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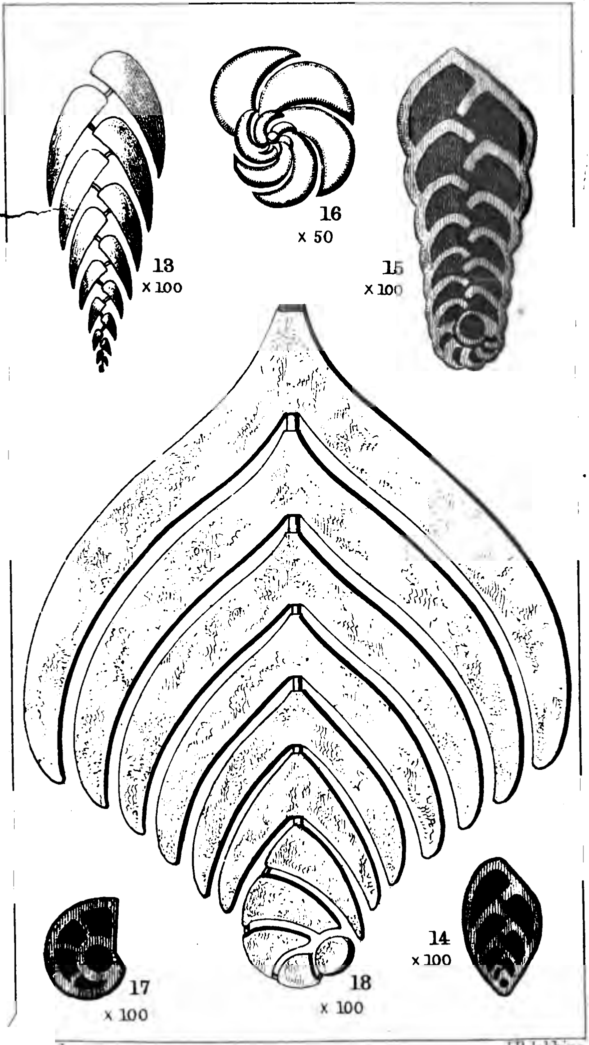
Plate III



GEOLOGY IN THE GARDEN;

OR, THE FOSSILS IN THE FLINT PEBBLES.

BY HENRY ELEY, M.A.

WITH ILLUSTRATIONS.

LONDON.
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ERRATA.

Page 78, line 6, *for* "with glaciers" *read* "their glaciers."
Page 78, line 7, *for* "and drift" *read* "in drift."
Page 80, line 24, *for* "London" *read* "Snowdon."
Page 150, line 4, *for* "large" *read* "larger."
Page 188, line 30, *for* "foraminifers" *read* "foraminifer."

GEOLOGY IN THE GARDEN.

CHAPTER I.

Geology as a source of rational amusement—Not pursued by some persons from a prevailing misapprehension—Other Popular Sciences supposed to be more accessible—None more attractive—Satisfactory to study it experimentally—Its conclusions surprising—Tangible proof peculiarly desirable—A portion of this proof easily obtainable where many persons would hardly look for it—Fossils round their homes—the Flint Pebbles.

No branch of popular science has more completely fascinated those who have occupied themselves with it than geology. But it has not recommended itself as a source of rational amusement to the notice of so many persons as it might have done, perhaps, because there is a prevalent impression that the experimental part of it is commonly out of the reach of those who are unable to leave home for the purpose of making distant excursions. The lover of flowers, who has acquainted himself with the elements of botany, is well aware that he need but walk into the nearest fields, and that he will easily find there what will put the knowledge he has acquired to the test of practice: he will soon gather numerous specimens; and it will occupy no small portion of his leisure time to apply the rules he has learned to the investigation of them. To assign to his plants their proper place in the system, to find out their names, to make himself acquainted with their qualities, to prepare them for the *hortus siccus,* and to lay them up for future reference, will furnish him with a pleasing and instructive engagement not to be very quickly exhausted. The entomologist who can devote only an hour or two now and then to his favourite study—and it is for the benefit of those who are otherwise much occupied that this little book is written—knows that he has not far to go to fill his boxes; he soon learns that a common, a wood, a pond, and the lanes leading to them—all of which he can look over cursorily in the course of an afternoon, perhaps—will be enough to supply him with interesting employment season after season. Nor will he be altogether unworthy of the name of a naturalist if he only become thoroughly acquainted with whatever even so small a field of observation as this will supply. But if geology should have attracted his attention, the inexperienced student is apt to fear that he can promise himself no such satisfactions as these. His chosen pursuit is one that, in interest, yields to no other whatsoever; but the book-shelf and the museum, he thinks, must be the limit of his resources, unless he is fortunate enough to be master of his own time, and has the command of a tolerably deep purse. And yet he cannot help feeling that the lover of this science, more than any one else, had need be well assured of the facts upon which his convictions are to rest. All that has excited his curiosity is so wonderful, so different from what he, perhaps, and the larger part of mankind, would have expected; there are so many mistaken notions connected with the subject, so many objections alleged against the conclusions to which the study of it has led; that it could not be otherwise than peculiarly satisfactory to him, since he is unable to search into the whole of the extensive and varied evidence upon which these conclusions stand, to have brought at least a portion of it, however small a one, to the test, by thoroughly examining and sifting it.

What is it that he is called upon to believe? That there was a world of living beings, or, in a certain sense, a series and succession of such worlds, before the creation of man! that the ground on which he at any moment treads, and the hills which bound his every-day prospect, were not placed by the Great Creator as those continuing monuments of His power which should endure unchanged from the beginning until the end of time; but that as, in obedience to His will, they were raised to their present level by the operation of natural forces at some former period of the earth's existence, so they may sink again at a future time, and leave—as plains and hills, upon several occasions within the historical period, have already left—a hollow to be filled with the waters of a lake, or a gulf to be washed by the tides of the sea!—that a considerable proportion of the dry land of the globe has been sea-bottom within a comparatively modern period!—that such has been the case, for instance, with the larger part of Europe!—that some of the highest portions of the Alps are within the area so lately covered by sea-water! Most of the conclusions which geology brings before him are of this startling kind; and he, and every one, must feel that it is not exactly satisfactory to take them altogether upon trust. I am told—he may be inclined to say—that the beautiful country upon which my eye now rests, apparently so firm and immovable, rich with growing crops, and adorned with stately trees, was once far beneath the waves; that it slowly rose through them; that the sterile surface so emerging was doubtless at first taken possession of by lichens, and other plants requiring little or no vegetable soil; that it could only have been fitted gradually, and in the course of ages, to be a suitable residence for the higher animals, and for man, as now it is: before I accept all this as truth, I cannot but desire to have the evidence of it made palpable, if it may be, to my senses: I am scarcely to be satisfied unless I can gather up with my own hands, from the places in which Nature has deposited them, and examine with my own eyes, some of the proofs which, as I am informed, she has so carefully preserved to give assurance of such an astonishing series of events as this.

It was with the design of helping to afford satisfaction to some of those who feel this want that the following matter was put together. If it should be objected that, after all, it is only a very small portion of the evidence desirable which is about to be considered, it may be answered that it is, nevertheless, conclusive so far as it goes; that it must needs carry conviction, to the minds of those who will examine it, of the soundness of several important geological deductions; and that it is all that can be reached, in an experimental way, by the persons for whom this little book is designed. Those who reside in the south-eastern parts of England, in the metropolitan and several adjoining counties, in localities where they have considered it hopeless, perhaps, to look for any proofs of the truth of this interesting science, may find the fossils to which they are here introduced close at home, and yet in the places where the sea left them. The search for them is not difficult; the optical help needed to examine them satisfactorily may be procured at the cost of a few shillings; they are highly beautiful in themselves, will occupy very little room in the cabinet, and are all but indestructible.

It may be proper to remark that the flint-stones concerning which we are about to treat, however familiar they may be to those who are used to them round London as the material of many of the roads, and almost all the foot-paths and walks, who know them as the prevailing pebble in the gravel-pit, scattered everywhere upon the surface of the ploughed fields and garden-borders, mixed with the soil as they see it moved for ordinary purposes, are, nevertheless, confined to certain districts; abundant in the counties nearest to the metropolis, they disappear as you travel towards the north-west, and are found dispersed very sparingly, on that side of England, beyond the river Avon in Warwickshire.[1]

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[1] Strickland, *Brit. Assoc. Reports,* 1837.

CHAPTER II.

Plan of the book to give explanations wherever needful—Chief truths of Geology, by way of introduction—Table of Fossiliferous Strata—Explanation of it.

Although it is by no means intended to treat of geology in general in the following pages, but to direct the reader's attention to one special spot in that wide field, of which, it is hoped, he will be able to obtain a satisfactory view, easily collecting for himself the needful fossils, and thus building up his argument, and resting his convictions, upon facts about which he cannot entertain a doubt; yet, for the sake of those whose attention has not been turned to such studies before, it may be desirable to say a few words concerning the leading truths of the science, and the manner in which they are established. As it is part of the plan of this book, however, to give explanations wherever the subjects discussed, or the terms used, may seem to require them, it will not be necessary to detain the reader, or try his patience, with a great deal of such prefatory matter.

No one whose curiosity is apt to be awakened by the contemplation of natural phenomena can travel in an undulating country by a newly-made railway, without having his attention fixed by the variety of earths and rocks which he will not fail to observe in the cuttings through which he passes. Gravel, clay, chalk, sand, limestone, sandstone, or minerals of rarer occurrence, may offer themselves to his notice in succession in the sloping banks, or upright faces close to his eye.

What does this mean? These materials appear to be arranged in layers one upon another, like the leaves of a book. Is this the construction of the earth everywhere? Has it been so from the beginning? Or do we see here the result of nature's subsequent operations? Do these beds themselves yield any information upon such points?

These are some of the questions which geology answers. It replies to many other inquiries, indeed, of great practical value for the encouragement of industry and enterprise, the development of a country's resources, and the advancement of its people in material comfort and civilization; but the first interest felt upon the subject will probably be one which will suggest such questions as we have supposed.

Now, an examination of the numerous strata, or layers, which are exposed to view in various parts of the world, has made it certain that this is the usual construction of the earth for a considerable depth below the surface; that it has resulted from natural causes, for the most part still in operation; that this crust of the earth is made up of a vast number of beds of greater or less thickness, and of varying extent—some being merely local, while others cover very large areas—which have been thrown down, one upon the other, the greater number as sediment from water, but not a few as lava streams from volcanic vents; that, with the exception of certain classes of crystalline rocks—granite, gneiss, and various kinds of schists or slates—which are chiefly seen in mountainous districts, and which appear to have been formed or altered beneath the earth's surface by the agency of intense heat, and to have been thrust up afterwards into their present position by the volcanic forces below, the whole of the dry land of the globe is, more or less, of this sedimentary character, or of molten matter which has been poured out from volcanoes, with an occasional bed of cinders or dust derived from the same source.

It is further seen that these layers[1] of sediment have been deposited in a series of unfailing regularity, so that wherever they are found together they always follow one another in the same order; that, inasmuch as each set of beds contains the remains of certain animals or plants, or of both one and the other, quite peculiar to the age in which it was deposited, it is distinguishable from all others with perfect certainty, no beds with the same characteristic fossils having ever appeared upon two different geological horizons, or levels—that is, higher and lower in the series; that there has been a succession both in the animal and the vegetable kingdoms from the very first, some kinds of animals and plants dying out, while new species have been created to take their place; and that every fact of the science tends to prove that these beds have required a vast length of time for their accumulation.

The reader will now be able to understand the annexed table of the fossil-bearing strata as they are found in the British Islands; which, with the accompanying explanation of it, will be all that is needful for him as an introduction to the following chapters.

---

[1] The words layer and stratum are indiscriminately applied to the beds of various kinds of which the crust of the earth is made up. Stratum is a Latin word, and signifies "strewn material," just as layer usually means that which is laid down in a similar manner.

Fossiliferous Strata in chronological order, or order of superposition, arranged in descending series, beginning with the newest, or recent.

I. Post-Tertiary Period.

Groups of Strata.		*Shells.*
1. Post Pliocene.	The more recent of these beds contain human bones, and articles fabricated by man; they represent or mark the human period. The earlier have no human remains; but the bones of land animals of certain species which are still found alive, and of others which are extinct.	All the fossil shells are of kinds which are still found living.

II. Tertiary Period.

2. Newer Pliocene; or, Pleistocene:	Still the bones of some land animals of living species.	Greatly the larger part of the fossil shells are of species still living.
3. Older Pliocene	. . . .	A large part of the shells are of kinds now living.
4. Miocene	. . . .	A small part only of the shells are of recent species.
5. Eocene	. . . .	An extremely small proportion of the shells are of kinds still in existence.

III. Secondary Period.

6. Chalk	None of the fossil shells are of kinds now living; but the strata are, nevertheless, distinguished by a difference in the shells, the more ancient kinds disappearing, while others come into view in their stead.
7. Green-sand and Wealden	
8. Upper Oolite, including the Purbeck . . .	
9. Middle Oolite	
10. Lower Oolite	
11. Lias	
12. Trias (Upper New Red Sandstone)	

IV. Primary Period.

13. Permian, or Magnesian Limestone (Lower New Red Sandstone)	
14. The Coal	
15. Old Red Sandstone, or Devonian	
16. Upper Silurian	
17. Lower Silurian	
18.* Cambrian and older fossiliferous strata . .	

---

* These eighteen "Groups of Strata" represent geological periods, though obviously of much shorter duration than those of the above four great Sections; they are spoken of as the "Pleistocene Period," "the Period of the Lower Oolite," "of the Coal," and so forth.

It will be understood from the table that the imbedded shells are taken, next to the order of superposition, as the chief means of distinguishing the several strata from one another, and of fixing their relative age.[1] This has arisen from the circumstance of their being far more universally distributed than any other kind of fossil, as it was likely they would be in beds deposited by water. Shells are also peculiarly valuable on account of the very wide range of individual species: since deposits of very distant localities, containing the same shell, may be thus shown to be of the same age. Moreover, the shells of the sea, of the land, and of fresh water, can be distinguished from one another. When, therefore, they are all three mingled together, as they often are in deposits formed at the mouths of ancient rivers, they show what species coexisted at that time, in the sea, on the land, and in rivers and lakes; and if any of either kind are found—as will probably be the case—in company with other fossils, they prove the age of these latter also. There is still another reason why shells, rather than any other kind of organic remains, are selected for fixing the chronology of the strata: as species, mollusks have a longer life than any other animals; the individual shell-fish may be comparatively short-lived, but its kindred continue on the scene a very long time. If the same kind of shell which is preserved in the Eocene strata is now among the living, that species has outlived many other species of animals which, introduced after it, have died out long before it.

But we are not to suppose that there are but few other fossils except shells. There is an abundance of such remains in many of the strata, and the evidence gathered from them is precisely in agreement with that furnished by fossil shells. Mammals,[1] birds, reptiles, fish, crustaceans,[2] insects, and zoophytes,[3] besides plants of various kinds, have all left their traces preserved in the rocks; and from all alike we learn the surprising fact that, in the course of ages, there has been more than once or twice an entire change of all things living upon the earth; so that those which occupied it at one time had disappeared from it at a subsequent time. M. Deshayes, a distinguished naturalist, has declared that, after surveying all the known fossil remains, he has discovered five great successive groups, so completely independent of one another that no species whatever is found in more than one of them.

---

[1] Sir C. Lyell, *Manual*, p. 115.

At all events, there can be no doubt that there has been a succession of species in the animal and vegetable kingdoms; but we must not hence infer that the whole series of fossiliferous beds could be divided into groups, whether more or fewer than five, so that each group should be independent of the two immediately adjoining, above and below it, having no species in common with them. Well-ascertained facts render it improbable that there were ever gaps of this kind separating groups. It is likely that, when the whole of the fossiliferous strata are thoroughly known, it may prove to be with every group as the table tells us it is with those of its two upper sections. A moment's examination of that portion of it will show that no set of beds is abruptly cut off from those next to it. The Pleistocene strata, for instance, which belong to the second section, or Tertiary Period, contain extremely few shells which are not found also in the first, or Post Tertiary section. There occurred between those two periods "no break or blank;" "on the contrary, many of the existing organisms were contemporary, during the morning of their being, with many of the extinct ones during the evening of theirs:" the two groups dovetailed into one another at a thousand different points.[1]

---

[1] Animals which suckle their young.

[2] Animals with jointed shells, as lobsters.

[3] Corals, &c.

Still it is to be understood that the four great periods, which are so convenient for classification, are sufficiently distinguished from one another by their fossil remains. These are seen to depart farther and farther from the living forms, in proportion as we descend lower in the strata, until it can be said, with reference to the animal kingdom of the Silurian group, that its "fauna bears in all its three great types the stamp of a fashion peculiarly antique; and which, save in a few of the mollusca, has long since been obsolete."[2] A few of the shells only of the Silurian beds are represented among those now living by others generically allied to them, though by no means of the same species; while everything else of that age is strange and quaint.

Nothing more need be said here about the groups of the Primary and Secondary Periods. It will not be necessary to trouble the reader with any further explanation of the table, so far as they are concerned, because they are not touched upon in the following chapters. But it is desirable that he should be acquainted with the chronological import of the names adopted in the classification of the beds above them, as they will be brought before him again. These were called Tertiary—from a Latin word meaning third—

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[1] Miller, *Testimony of Rocks*, p. 122.

[2] Ibid. p. 58.

because they come next above, and are posterior to those which, for certain reasons, had received the name of Secondary. It was Sir C. Lyell who, in 1828, conceived the idea of dividing the Tertiary Strata into four groups, each characterized by the number of recent species it contains in every hundred of its fossil shells; the other kinds, which make up the hundred, having of course died out since the beds were deposited.

He thought that the oldest Tertiary beds yielded about 3½ per cent. of species still living; that the beds next above them in the series might contain about 17 in the hundred; that those still higher, or nearer the present time, furnished from 35 to 50; and that the uppermost strata produced from 90 to 95 per cent. of kinds still living.

To these four groups he gave names expressive of the proportional number of recent species which each contains.

The lowest he called Eocene, from two Greek words, *eos* the dawn, and *kainos* recent—to signify that these beds were deposited at the dawn, or first rise of the living species of animals of this kind; all the species of mollusks,[1] the shells of which are found in the beds below these, are extinct.

The set of beds immediately above this he named the Miocene—from *meion* less, and *kainos* recent—to indicate that they contain a smaller proportion of recent species than the group which comes next in the ascending order.

To this latter, then, he gave the name of Pliocene, or Older Pliocene—from *pleion* more, and *kainos* recent,

---

[1] Shell-fish in general.

—because it yields a proportion of recent species greater than does the Miocene.

To the uppermost of the four groups he applied the name of Newer Pliocene, which has been since changed into Pleistocene—from *pleistos* the most,—because its beds furnish by far the largest number of recent species in proportion to those which have died out.

It will be observed that these names refer exclusively to the fossil shells which are found in the strata, and have no relation to any other organic remains which they may contain.

And "it may assist the memory of students," says Sir C. Lyell, "to remind them, that the *Mi*ocene contain a *mi*nor proportion, and the *Pl*iocene a comparative *pl*urality of recent species; and that the greater number of recent species always implies the more modern origin of the strata[1]"

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[1] *Manual,* p. 117.

CHAPTER III.

Minute Fossils not less instructive than those which are more conspicuous—Of more importance in the strata—Paris built of a stone made up of such fossils—The material of the Pyramids of Egypt not very different—Strata of a like origin hundreds of feet in thickness—Flint Pebbles the prevailing stones in the gravel of south-east of England—Common mistakes about their history—Almost all contain fossil remains—Apparatus needed for search, simple—Not expensive—Best method of finding, displaying, and securing these fossils.

Of the thousands of persons who are going every week to wonder, and with good reason, at the strange forms presented to them by the beautiful models of the fish-lizards—*icthyosauri*—and the more monstrous reptiles which are so appropriately placed on and about the geological island at the Crystal Palace at Sydenham, few, perhaps, are aware that the pebbles of the gravel-walk which leads down to that island contain abundance of most perfectly preserved fossil remains, which, if they are almost infinitely smaller than those which have introduced the palæontologist[1] to the knowledge of the grim giants which they see represented before them, are not less really marvellous when all the circumstances under which they are found are taken into the account; and prove some of the great truths with which geological science makes us acquainted, with no less certain demonstration. It will indeed be shown, in a subsequent r, that if we regard the vastness of the monuments l up by these little creatures, and the importance remains they have left as constituent portions of the earth's crust, they are beyond all comparison of greater interest than the colossal races which attract so much more notice. The bones of the latter occur here and there imbedded in certain strata; but the very rocks themselves, in mountain masses, owe their existence to the former. "Nature," says Ehrenberg, "placed these minute organisms, in individual energy, far below lions and elephants, but in their more general social influence far above them." Paris is built of a stone made up of the shells of similar animalcules, and the material of the Pyramids of Egypt had a like origin. Existing in countless myriads in seas favourable to their increase, their harder parts can be shown to have accumulated, with little addition, to the thickness of many hundred feet. However minute in themselves, then, they have played a most effective and conspicuous part among living creatures; they have left memorials of their existence of the utmost value to the present inhabitants of the earth, and of such extent that all which remains of the larger animals, when placed beside them, and viewed in this light, is insignificant.

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[1] A person learned in fossil remains.

It is no doubt very generally known that of the pebbles which occur, whether in the gravel-pit or elsewhere, in the south-eastern part of England, by far the greater number are flints. There are stones of other kinds—some of them abundant enough—such as sandstones of various sorts,—those of a proper size and shape being familiar to us as paving-stones in stable yards and cellars,—and small rounded pieces of white or yellowish quartz,—alabaster stones, as children mistakenly call them; for alabaster is a lime-stone, and these are silex; but the common flints greatly preponderate, not a few of them, as we shall show hereafter, unbroken, but the majority in a state wholly different from that in which they appear in their native place.

It is probable that if persons were asked the history of these pebbles, many of them would answer that they were a portion of the original materials of the earth; that, for the most part, they had lain as they are from the beginning; for that although the labour of man had brought some of them up to the surface, yet, by digging deeply enough, fresh ones would be found which had not been moved, and certainly had not seen the light, since they were called into being. It would be thought by others, perhaps, that these stones were formed by the infiltration of water into the bowels of the earth, somewhat in the way of crystallization, or petrifaction, so that the process was for ever going on, —that stones grew, in short. This last is a very prevalent notion in some places, where persons will point out what they call breeding-stones, which are nothing more than masses of gravel cemented together by an oxide of iron, or rust, which happens to be present in unusually large quantities, and which, from its ferruginous colour, is generally very apparent. These loose conglomerates, when exposed to the action of the atmosphere, gradually fall to pieces, and thus, it is thought, a supply of pebbles is kept up, the mother-lump being formed under the ground, to scatter its stony progeny as they are ready to leave it. A little examination of the facts of the case will lead to conclusions very different from these, and of no small interest.

If a common flint of a few ounces weight be broken, its semi-transparent, or at least translucent inside will generally present a more or less spotted appearance; the smooth broken surface may be black, or grey, or some shade of brown; but it will almost always have white marks about it. These are not uncommonly fossil remains. This general name is applied to anything which, found in the rocks which constitute the earth's crust,[1] indicates the former presence of an organic body, whether animal or vegetable. The true character of many of these white patches, though consisting perhaps of the remains of minute organisms, cannot oftentimes be satisfactorily made out, because the entire individuals, and the fragments, are so closely heaped and pressed together, that there is no possibility of discerning their particular forms. But round the edges of these clouds, where the white dust seems to have mixed more sparingly with the clear flint, the beautiful little fossils may be discovered floating, as it were, like insects in amber, or fruits in a clear jelly. It is no doubt an inconvenience that, in consequence of their being immovably fixed in their resting places, they can be viewed, generally speaking, only on one side. Very many escape detection in consequence, especially by the young beginner, who is not yet sufficiently well acquainted with their various shapes to recognise them in every position. But they occur in sufficient abundance to render this a matter of little consequence. A diligent search will not fail of being sufficiently rewarded.

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[1] In geology the word *rock* is used for any of the strata, layers, or beds into which the earth is divided, whether of hard stone, or of less coherent materials. Thus granite, marble, chalk, clay, or a stratum of loose sand, are all equally *rocks*. The *earth's crust* is that thickness of these strata which is, in one way or another, open to our investigations: it may extend to eight miles or more.

In the Appendix will be given a descriptive list of a considerable number of these fossils, with lithographic illustrations. At present we will endeavour to explain the best methods of finding, displaying, and securing them.

The flints contain a variety of organic remains, some few of considerable size, and many that are easily enough seen; but the greater number of those to be hereafter described are not upon an average larger than the full stop at the end of this sentence. They are chiefly very beautiful in form: their symmetry cannot be surpassed; but, of course, it is not possible to examine anything so small as they are without the help of magnifying glasses. All that is needful in this way, however, may be purchased for a few shillings, and will be useful to those who are investigators of nature generally for many other purposes; indeed, is essentially necessary for such pursuits. A botanist's double glass, which costs four shillings and sixpence, and a Coddington lens, worth from six shillings and sixpence to ten shillings, are sufficient; or for this latter might be substituted, if the difference of price should be an object, a Stanhope lens,[1] the value of which, in its case, is only four shillings and sixpence.

Thus furnished, and having procured from the chymist, for a few pence, a small bottle of Canada balsam, which is the best varnish for the purpose, the student will be ready to commence the search.

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[1] If it should be determined to adopt the Stanhope lens, the optician must be requested to select one which has as long a focus as may be; in some of these lenses the focus is so near the surface of the glass that there is a continual risk of scratching, and so of spoiling them.

Although there are few flints which are absolutely without fossils, yet some are far better worth his attention than others. Those are the best of all, perhaps, which, upon a tolerably translucent black ground, have somewhat large opaque white spots about them, such spots being surrounded by a white dust, floating, as it were, in the clear flint. Among these specks there are probably many fossils, some of which may be in a position favourable for examination.

A promising flint having been found, care should be taken to make the most of it by breaking it up into thin wedges, across the fossil spots, by striking it on the outside with the edge of a small hammer. As smart blows must be given, which will scatter the fragments, the eyes should be protected by a veil of muslin. The flint having been thus broken up, and the pieces wetted with clear water to make them more transparent, they must be carefully searched over with the double glass, and wherever anything is discovered which looks like a fossil, a circle should be marked round it with the point of a pin. The flint having been wiped quite dry, the marked spot is to be covered with a thin coat of Canada balsam, and it will be ready for examination under the Coddington lens.

The adroit use of this higher magnifying power, though by no means a difficult accomplishment, will not be attained without some careful practice. Holding it by the handle, close up to the glass, between the thumb and forefinger, one must rest the ends of these fingers on the face of the flint, and thus as firm a position, and as accurate a focus may be obtained, as though the whole were fixed in a frame.

Nothing answers better for the application of the Canada balsam than a piece of slate-pencil ground to a point: the varnish while fresh may be wiped from it by means of a piece of wetted paper, or it can be scraped off with a knife should it accidently harden upon it. Metal is objectionable for this purpose, as even steel may leave a mark upon the harder flint, and would thus, perhaps, spoil a valuable specimen.

It will, of course, occasionally happen that the flint is so broken as to expose the very substance of the fossil on its surface. This will be known by its white and chalky appearance while dry, or from the faintness of its outline when wet; it has then absorbed the water. In this case the Canada balsam would also be absorbed by it, and the fossil hopelessly obliterated. Under such circumstances a piece of wetted gum arabic may be rubbed upon it, instead of the balsam: it will render the flint transparent enough, perhaps, and will certainly do no harm, as the fossil will return to its white appearance as soon as the gum is dry.

A very convenient way of mounting the specimens is to fix them in a piece of a common wine-bottle cork. A slice of the cork should be cut with the top and bottom parallel to one another: one cork will generally supply three stands. A rectangular notch must then be made in the top of the cork, of sufficient width and depth, and, the material being elastic, the piece of flint may be slipped into it, to be held, at any convenient angle, as if it were in a pair of tongs. The flints may be trimmed to a suitable size, if placed upon an edge of iron, and cut with the sharp end of the hammer. If a fossil should be too deep down in the flint for a good view, the thickness may be reduced to any extent by rubbing it on a wetted sandstone, such a one as any gravel-pit will supply; or by the help of a blacksmith's grindstone, which is a much quicker process.

But a very abundant supply of fossils may be obtained under conditions entirely different from those already described. Many of the larger flints, upon being broken, will be found to have cavities within them containing a mealy substance, either loose, or adhering, more or less firmly, to the surrounding stone. This dust is now and then almost all fossils, and is seldom altogether without them. For the display of them, however, a peculiar treatment is required. A small quantity of the powder must be put into a phial, or, which is better, a test-tube,—which the chymist will supply for twopence,—and thoroughly, though carefully, washed. By washing is meant that same process which the gold-seekers adopt at the diggings: the meal is to be shaken up with several supplies of fresh water, which are to be successively poured off from it until no milkiness remains, but only the heavier sediment which sinks pretty quickly to the bottom. It is necessary to separate this residuum again into two different parts, the coarser and the finer, or it cannot be examined quite successfully. This may be done in various ways; but in no manner so readily, perhaps, as by means of a piece of a chymist's glass tube or pipe, a few inches long, and a quarter of an inch or less in diameter. Hold the finger tight upon the top of the pipe, so that the air contained in it may keep out the water, and lower it down into the test-tube until the end of it is just over the sediment. Lift the finger off for a moment, and the water will rush up into the pipe, and bring the sediment with it. Close the pipe with the finger again, and the water, and the sediment in it, may be drawn from the test-tube together. Suffer the first drop, into which the larger fossils will instantly sink, to fall off upon a piece of slate, or other smooth substance of a dark colour; and let a second drop, with the sediment which comes next, deposit itself on a piece of glass: there will still be a finer residuum, but this may be thrown away, as it will be beyond the reach of the Coddington lens, that being of hardly high power enough for its investigation. The larger fossils can be picked out with a needle by the aid of the double glass; with the smaller there must be a different mode of proceeding. Dry the water from them thoroughly by holding the glass over a candle. Then put some balsam upon one side of another smaller piece of glass, which should be just large enough to cover the whole of the fossils easily, and drop it down upon them. With a split cork as a pair of tongs, hold the two glasses for a few minutes, in a horizontal position, over the flame of a candle, keeping them as hot as you possibly can without actually boiling the varnish; and when cold, if all has been properly managed, the balsam will be firmly set, and the fossils in it, between the two glasses, quite transparent. They can then be sufficiently well seen with the Coddington lens, by holding them up against the light.

It may be as well to note here, perhaps, that these fossils, and those which float in the substance of the flint, though of course identical in their origin,—we speak particularly of the minute shells called foraminifera,—exist at present, as has been already said, under very different conditions. In one case—that of the solid flint—we see nothing but a cast of the interior of the shell in some white substance—chalcedony probably: in the other we have a substitute, either in carbonate of lime, or flint, or partly one and partly the other, for the shell itself,—a cast of the shell, indeed. In the imbedded fossil the cast of the shell, although it is certainly there, is often invisible; for it is as transparent, generally speaking, as glass: in that from the flint cavity, on the other hand, the matter which has taken the place of the shell is seldom very clear, and it is occasionally filled with a substance of a darker hue. In this condition, when mounted between glasses, and viewed as a transparent object, it is sometimes highly beautiful, exhibiting the peculiarities of its structure in a remarkable manner (see Figs. 14, 15, and 17, Pl. III.).

CHAPTER IV.

Native place of these flint pebbles—The chalk—Contains layers of flints—With the same fossils—The chalk flints differ in appearance from the pebbles—Chalk flints rolled into similar pebbles on sea-shore—Coating of the pebbles caused by decay—This proved by Hertfordshire pudding-stone—Pure quartz does not decompose like common flint—Larger fossils in gravel-pits—And unrolled chalk flints among gravel—Confirm the fact that flint pebbles come from chalk—They obtained their fossils from the chalk—Which is in great part made up of such remains—Origin of flints in chalk—Decomposition of felspar—Hot springs holding silex in solution—The geysers — Difficult question—Does not concern our argument.

HAVING satisfied ourselves of the existence of organic forms, in considerable number and variety, under circumstances of such little promise as those in which we have now seen them,—for we could hardly expect to find the remains of living creatures in the inside of a flint-stone,—we shall be curious to learn whence they came.

Most persons, perhaps, have seen a chalk country,—a district in which the subsoil is chalk. This part of the cretaceous formation—chalk, properly so called,—which attains in some places a thickness of many hundred feet, may be separated into two great natural divisions, the upper and the lower chalk. Of these the upper is much the softer: it is this which is used as a material for writing upon school boards, and for other similar purposes. This upper, or soft chalk, is found marked out into strata, as it were, by layers of flint. Sometimes this flint, which is usually only a few inches in thickness, occurs in an unbroken sheet; but its prevailing condition is that of nodules,—lumps of a more or less rounded form; though often of a shape so irregular and grotesque as to have made them a favourite ornament in cottage gardens, where they may be seen, neatly whitewashed, as edges to the flower-borders (see Fig. 63, Pl. XII.). If these chalk flints be broken, we shall find the inside of them agreeing with the pebbles of our surface soil and gravel-pits, not only in general appearance, but in fossil contents: we shall see in them the same animal remains, in the same condition, and in the same relative proportions; those species which are the most common in the stones with which we are so familiar, being likewise most abundant in the chalk flints. In short, we cannot entertain a doubt that the one kind of stone has some close relation to the other. In outward aspect, indeed, they, for the most part, differ greatly. The flint from the chalk-pit is not unfrequently of considerable size and weight; often throws out arms, or divides into a fork; has depressions and protuberances about it not altogether unlike those of a kidney potato; and is covered with a thick coating of uniform chalky appearance. Our ordinary pebbles, on the contrary, are chiefly compact, egg-shaped stones (see Fig. 62, Pl. XII.), of a much smaller size, having a coating, indeed, but by no means always of one colour; and are either marked with a multitude of scars and scratches, greatly resembling one another in all instances, as though resulting from some one similar cause; or else, if they are quite small, are smoothed and polished.

Now it so happens that, on several parts of our coast—in Sussex, Kent, and Norfolk, for instance—the sea is undermining the chalk cliffs, and breaking up, and grinding, and polishing the flints which fall out of them, according to their size, the heavier pieces being roughly scarred on the outside by the weight of their fall as the breakers throw them over, while those which are so small as to be moved by the lesser waves, are more gently rolled about until they are quite smooth; and no one can watch the process without seeing that the pebbles which are thus manufactured are identical in almost all their outward characteristics with those which are so prevalent inland. In this respect alone they are dissimilar, that the newly-rolled stone, although shattered on the outside like the others if of larger size, and polished if it happens to be quite small, has no coating whatever; when broken, it is alike in colour and appearance right through its substance; while the pebble of the gravel-pit is surrounded by a rind, as it were, of a colour different from that of the rest of the stone. This circumstance is easily accounted for, however. Flints, although made to endure a long while, are by no means imperishable. Silex, or flint in its purest state, continues unaltered for ages. We are familiar with this in the case of the small rolled pieces of white quartz which are everywhere associated with our flints: they have no coating, that is, there is no visible tendency in them to decay. But common flints, when exposed for a great length of time to the influence of the weather, gradually perish. This is the meaning of their faded-looking outsides as we see them in the gravel; they are in process of decomposition. They are not pure flint; they contain metallic oxides—iron, or manganese, or alumina; or else lime, or bituminous matter,[1] in various proportions; and so they are easily acted upon by the water which soaks into them, and, in the course of time, are resolved into their elements. The bands of colour—red, yellow, or brown,—which are often to be seen in flints, are only an indication of the same thing: they are being gradually decomposed. That such is the case may be easily proved. There is a very commonly-occurring conglomerate, called Hertfordshire pudding-stone (see Fig. 58, Pl. XII.). It consists of small rolled flint pebbles and sand, held together by a siliceous cement. It is not a very unusual thing to meet with pieces of this hard conglomerate which have themselves been subjected to the action of moving water, and rolled into boulders. The general surface is shattered and scarred, like any other water-worn stone, and the whole outside has the ordinary indications of decay. If now such a mass be broken, so that some of the contained pebbles are set free from the paste in which they are fixed, they will be often seen without any appearance of coating; they will be found to be as fresh on their outsides as those just rounded by the waves on the sea-shore. They have been effectually protected from the weather, and have at present no apparent tendency to decomposition. The same fact is exemplified when crystals of quartz happen to be exposed on the outside of a decaying flint, which is a sufficiently common occurrence. They remain unchanged, reflecting all the sun's rays as brilliantly as ever, while the surface on which they were formed, not being pure flint, is obviously perishing. "In quartz, or rock crystal, which is pure silex, and in other regularly crystallized bodies," says Sir D. Brewster, "their molecules or atoms unite in virtue of regular laws, the pole of one atom uniting with the similar pole of another. Such substances, therefore, do not decompose under the ordinary action of the elements. The lens of rock crystal, for example, found by Mr. Layard at Nineveh, is as sound as it was many thousand years ago, when in the form of a crystal." The difference, therefore, between the flint now being rolled on the sea-beach, and that which is picked from the surface inland, is simply that the one is recently ground, and the other is weathered.

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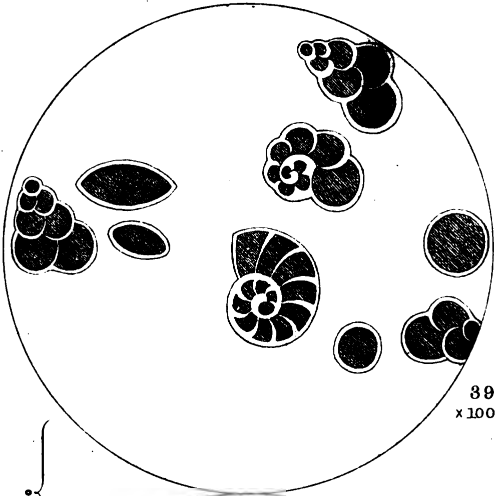
[1] The dark colour of flints is owing to some such substance of organic origin. Dr. Turner, Edinb. New Phil. Journ. vol. xv. p. 254.

Our gravel-pits themselves afford sufficient confirmation of the fact that their contents are chiefly from the siliceous layers in the chalk. Here may be found flints, with impressions of such shells or other organisms upon them, as are well known to be common in the chalk flints (see Figs. 59, 61, and 62, Pl. XII.). Other fossil remains, having the same origin, are scarcely less common. At Fig. 54, Pl. XI. is represented an echinite—a fossil sea-urchin—the *Ananchytes ovatus*, broken out of a flint from the gravel-pit. On the side where the fossil was exposed—as at *a*—it is water-worn, like any other pebble; while on the opposite side—at *b*—where it was covered by the flint since broken away to display it, all the delicate raised lines and studs are quite uninjured, and it is at once seen to be a common chalk fossil. Ventriculites again, or fossil mushrooms, as they are called in some places (see Figs. 48, 49, 50, Pl. XI.), are equally abundant in the chalk strata, and wherever the flints of the chalk may be scattered; but this point will be further illustrated in the Appendix.

To complete this part of the evidence it need only be pointed out that the gravel-pit and surface soil, though in the midst of a clay country of forty miles across, perhaps, will furnish thousands of unrolled and unbroken flints, in no respect differing from those of the chalk (Fig. 63, Pl. XII.), except that their original white coating has become stained, more or less deeply, with the ochreous colour of the gravel, or with the darker hue of the vegetable mould in which they have been imbedded. It may be concluded, without any hesitation, then, that the flints from these very different localities had the same origin.

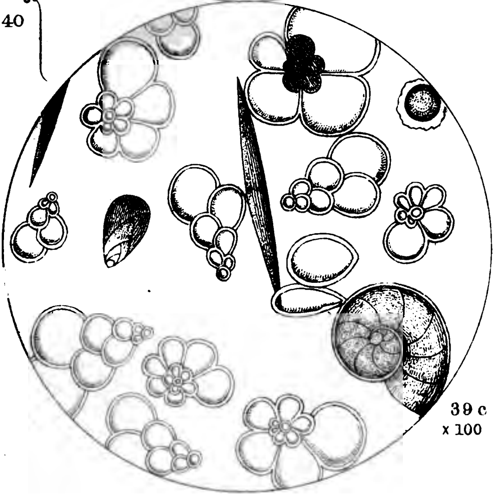
But whence have they obtained the minute fossils which, as we have seen, make part of their substance? Any one can procure a small piece of common chalk; and no kind is better for the purpose than the soft chalk used by carpenters, or in schools, for marking on boards. Having soaked it for a few days, let him gently brush it under water, and wash the resulting sediment, and proceed with it precisely as was directed at p. 22, in the case of the dust from the flint cavity. His examination, whether of the larger grains, or of the finer particles, will leave no doubt upon his mind that he has found the great depository of his fossils: the chalk abounds with them. It has often been affirmed that this vast formation of white limestone is nothing but a heap of fossil remains of marine creatures, either whole or in a fragmentary state. And it is probably true, if in the latter phrase is included that portion of those organisms which has passed through the bowels of fish, mollusks, or marine worms. At

Plate VII



39
x 100

40



39 c
x 100

H.E. del.

J.R.Jobbins

Pl. VII. Figs. 39 and 39 c, are given two representations of the field of the microscope, magnified about a hundred diameters; Fig. 39, with the dust from a cavity in a flint from the gravel-pit; and Fig. 39 c with chalk; in either case the mere shapeless fragments are omitted. A glance will suffice to convince any one that the fossils from these two sources are the same, although the conditions in which he sees them differ considerably. Those from the chalk are casts of the empty shell in carbonate of lime; for the shell itself has disappeared, and its place has been taken by this substance: in those from the hollow flint, siliceous matter, probably, represents the shell, and flint of a different colour—chalcedony, perhaps,—has filled up the interior; occasionally they are altogether, or in part, made up of lime, like those from the chalk.

The Figures in Plates VIII. and IX. which have a c besides the number, represent fossils from the chalk corresponding with those from the solid flints which, in Plates II. III. and VI. have the same number without the c: the same number shows the same animalcule, from one source or the other; so that a further comparison may be easily made, and their identity recognised. It should, however, be borne in mind, that the outside of the shell and its interior must needs differ somewhat in appearance, the thickness of the two walls occasionally reducing its width much more in proportion than its length. Some of the individuals figured are, moreover, of larger growth in the one case than in the other, as, in these instances, we have no specimens of exactly the same size. Indeed, it will be readily understood that, in the case of the fossils immersed in flint, which are not always easily discovered, the full-grown are those which more quickly catch the eye; and hence it will happen that the specimens so collected will be, on the average, larger than the same species found in the chalk.

We shall, of course, wish to know the origin of the flint in the chalk, and under what circumstances it enveloped, and oftentimes converted, as it were, into its own substance the organisms of which it laid hold; for it will be found that, not only many of the fossils which are inside the flints, but some of those which adhere loosely to their white outside coating, have parted with their lime, and have appropriated siliceous matter instead. These are questions which have been answered in different ways—answered conjecturally; for no satisfactory proof has as yet been offered to show that any of these solutions of the difficulty is the right one.

That flint, in some condition in which it has been often present in the water of the sea and elsewhere, has a tendency to replace other matter in decaying organized substances, there can be no doubt. Casts of shells and corals in flint are common; silicified trunks of trees are abundant in many places; and the numberless echinites, ventriculites, and sponges of various kinds, supplied by the chalk strata, in which silex has preserved the form of these several organisms, while their original substance has wholly disappeared, make this fact plain to every observer. When *a cast in flint* is spoken of, however, it must not be understood that a mechanical operation, like the pouring of molten metal into a mould, is always meant. The phrase is often used to express a chemical process, in which an organic substance being removed, particle after particle, by decomposition, a mineral takes its place in the same order, being deposited from a simultaneously decomposing solution, perhaps. In this way it is not thought difficult to account for the fossil forms in which the flint is found. Some geologists and chymists, indeed, suppose that chalk flints in general are zoophytes thus fossilized by silica; and that the more carefully the flint nodules are examined, the more frequently will traces of organization be found in them. To the truth of this latter observation of Dr. Turner any careful observer will bear testimony: a very considerable proportion of these stones afford manifest proof that they have been gathered round sponges and other organisms of that kind.

But there still remains the difficulty of accounting for the presence of the silex in the sea-water under such circumstances as would be likely to have produced all the effects observed. The flint, it is to be recollected, is not diffused equally through the whole mass of chalk, but occurs in beds usually from two to four feet or more apart, the intervening stratum of chalk having only an occasional flint in it. In some few localities large urn-shaped flints, called pot-stones, form an exception to this rule, as they are continued perpendicularly, looking something like a jointed column, from one layer of flint to another. But, generally speaking, the courses of flint are perfectly unconnected; and, if one of them were to be laid bare, it would present an appearance not very much unlike an ordinary pavement of boulder stones.

It is certain that rivers draining countries in which that very prevalent substance felspar is undergoing decomposition—and it decomposes rapidly under certain conditions—must bring down to the sea enormous quantities of its silex in solution; and organic substances in a decaying condition might cause it to be deposited in the manner intimated above. But this hypothesis does not account for a periodical prevalence of silex, or for its deposition at intervals. It has been suggested, therefore, that the layers of flint are due to the occasional outburst of hot springs, holding large quantities of this mineral in solution. That many such springs yield silex in abundance is very well known. The Geysers of Iceland are a familiar instance. The largest of those strange fountains plays in a spacious basin of flint, fifty-six feet in its greatest diameter, which occupies the top of a circular mound of the same material, the whole of which has resulted from siliceous incrustations deposited by the water as it has evaporated. We will conclude with a quotation upon this obscure subject from Sir Charles Lyell's Manual. Having observed that the origin of these layers of flint is "difficult to explain," and that "no such siliceous masses are as yet known to accompany the aggregation of chalky mud in modern coral reefs," he says, "Some portion of the flint may have been derived from the decomposition of sponges and other zoophytes provided with siliceous skeletons; for it is a fact that siliceous spicula, or the minute bones of sponges, are often met with in flinty nodules, and may have served at least as points of attraction to some of the siliceous matter when it was in the act of separating from chalky mud during the process of solidification. But there are other copious sources whence the waters of the ocean derive a constant supply of silex in solution, such as the decomposition of felspathic rock, also mineral springs rising up in the bed of the sea, especially those of a high temperature;

since the waters, if chilled when first mingling with the sea, would readily precipitate siliceous matter. Nevertheless, the occurrence in the white chalk of beds of nodular and tabular flints at so many distinct levels, implies a periodical action throughout wide oceanic areas not easily accounted for. It seems as if there had been time for each successive accumulation of calcareo-siliceous mud to become partially consolidated, and for a re-arrangement of its particles to take place (the heavier silex sinking to the bottom) before the next stratum was superimposed; a process formerly suggested by Dr. Buckland."[1]

It may be here observed, however, that these questions do not at all concern our argument. In whatever manner the flints were formed in the chalk sea, it is certain that there they were formed. The inquiry we have to answer is, How did they make their way from the chalk strata to the distant localities in which we find them?

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[1] *Manual,* p. 244.

CHAPTER V.

The chalk formation—Its extent in England—A marine deposit—Whole area of chalk originally under water—Since upheaved—Chalk strata greatly disturbed—Extensively washed away—This exemplified in the Weald of Sussex—Flints of eastern counties not from Weald—Disputes among geologists much exaggerated.

If we next turn our attention to the present aspect of the chalk formation,[1] we shall have abundant reason to think that that great deposit has been so much disturbed by a power which has been at work beneath it, and acted upon by water in motion on its surface; we shall be convinced that such vast masses of it have been swept away, and carried we can only conjecture whither; that we need not be surprised at finding its flints broken into fragments and rolled into pebbles, as they are now to be seen, in the districts which have been indicated, mixed with the surface soil and in the gravel-pit. We shall still have to account for their presence, in an unbroken and unrolled condition, so far off the chalk as we continually meet with them in that state; but, however many of them may occur with the marks of violence about them, we shall be at no loss to determine the nature of the force by which they were shattered and rounded; since the breakers on our coasts, as has been already observed, are working exactly the same effects at every moment of time.

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[1] A formation is an assemblage of rocks or strata which have some character in common.—Sir C. Lyell, *Manual,* p. 3.

If we take a map of England, and draw a line from about Bridport, in a north-easterly direction, through Blandford, Marlborough, Wendover, Hitchin, Mildenhall, and so to Hunstanton on the Wash in Norfolk, we shall find that nearly the whole of the country to the east of it, comprehending the counties of Suffolk, Essex, Middlesex, Kent, Surrey, Sussex, and Hampshire, almost all Norfolk, Hertfordshire, and Dorsetshire, and parts of Cambridgeshire, Bedfordshire, Buckinghamshire, Oxfordshire, Berkshire, and Wiltshire, has chalk on the surface, or within a certain moderate depth beneath it. Throughout that wide region, with the exception of what is called the Wealden, or Weald Valley,—a considerable tract, extending over parts of Kent, Surrey, and Hampshire, and almost all Sussex,—chalk is one of the strata of which the earth's crust consists, rising for the most part, wherever it reaches the surface, into elevated downs, and not unfrequently into lofty hills, some of which attain a height of from eight hundred to nearly a thousand feet above the level of the sea.

Now, that this chalk is a marine deposit, its constituents abundantly prove. That this whole country, then, was once beneath the waters of the ocean is manifestly certain. Whether the level of the sea was, at one period of the earth's history, very much higher than it is now, or whether this vast mass of chalk has been raised up out of it, sure we are that salt-water once covered it all; for it is itself the produce of an ocean, in which alone the animalcules, and other creatures of whose remains it consists, could have lived and multiplied. While geology was in its infancy, the opinion was general among those who inquired into such matters,[1] that the waters of the earth had been so much lowered, by some means or other, that entire continents, which had once been altogether submerged, were left dry. Not being aware that volcanic forces were actually in operation, sometimes under their own feet, and were, however slowly, upheaving or letting down extensive areas of the solid crust of the earth, with all their inhabitants upon them, it seemed, they thought, more reasonable to account for what they saw by supposing that the water had subsided, than that the earth had been upraised. But then they were utterly unable to conjecture whither this enormous volume of water had retired. Shells, and other marine remains, were found in profusion even to the very summits of lofty mountains. The whole, therefore, must have been covered at least to this height; for water cannot do otherwise than find its own level. What could have become, then, of so vast a body of it as this? Imagination was altogether baffled while attempting to account for its disappearance.

As soon, however, as this insuperable difficulty was avoided by supposing that the height of the land had varied, while the water had always maintained the same level, geologists perceived that it was now easy to account, in a simple and natural manner, for other phenomena by no means satisfactorily explained under the former hypothesis. It had been ascertained, upon unmistakable evidence, that in many places the earth's surface had undergone repeated changes; that an area, for instance, which was once covered by the sea, had been subsequently dry land, then the mouth of a tidal river, a second time sea, and then again laid dry,—having remained in each of these successive conditions for some considerable space of time. There was no difficulty in understanding these appearances upon the supposition of changes in the height of the land over these limited areas; while, under the other theory, it was necessary to inundate the whole globe with salt-water, and drain it off again, more than once, to account for the fluctuations which had occurred in any such locality; and, moreover, to repeat this process, over and over again, at very different periods in the earth's history; for a like series of changes had certainly happened several times, with intervals of immense length between them.

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[1] Sir C. Lyell's *Elements*, chap. v.

It was further seen that, although the beds of sand and shells, and other marine deposits, were occasionally horizontal, as water would usually leave them, they were more commonly tilted, and inclined at various angles to the horizon; or bent and folded; or set vertically upon their edges; in short in almost any position rather than that in which they would have been strewn at the bottom of the sea. Such disturbance of the strata was quite in agreement with local movements of the earth's crust by volcanic forces acting beneath it; while it could not have been brought about by any rise or fall in the level of the waters on its surface. "Geologists, therefore," says Sir C. Lyell in his Manual,[1] to which we are indebted for the chief part of the facts and arguments of this chapter, "were at last compelled to have recourse to the doctrine that the solid land has been repeatedly moved upwards or downwards, so as permanently to change its position relatively to the sea. There are several distinct grounds for preferring this conclusion." He then points out that it agrees well enough with the position of those elevated masses of marine origin in which the stratification remains horizontal. Such, for instance, are the strata met with in the south of Sicily, filled with shells for the most part of the same species as those now living in the Mediterranean, but raised at this moment to the height of more than two thousand feet above its level. Such again is the Table Mountain at the Cape of Good Hope, where stratified sandstone, no less than 3,500 feet in thickness, maintains a perfectly horizontal position: and many other well known examples of the same kind might be cited. It is true that a lowering of the general level of the sea would be equally consistent with these appearances: but they are not inconsistent with the other hypothesis; since elevatory forces, acting uniformly throughout large areas, as they certainly do act, would upheave the strata without altering the position in which they were deposited. While, on the other hand, the sinking of the water would offer no explanation of the still more prevalent phenomena of marine beds strewn horizontally, now broken, inclined at various angles, curved, and even set on end, which is by no means a very unusual circumstance. A moment's inspection of such a disturbed region would convince any one that the contour of its surface must have been greatly altered while it was subjected to the violence of which so many marks are apparent. There is no kind of proof, again, that the sea has ever undergone a change in its level in any region whatsoever; while it is well known that the land has experienced upheaval and depression in many places since the advance of science has qualified observers to ascertain the fact beyond the possibility of doubt.

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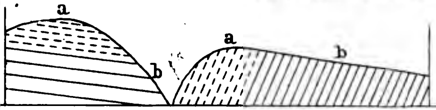
[1] Chap. v.

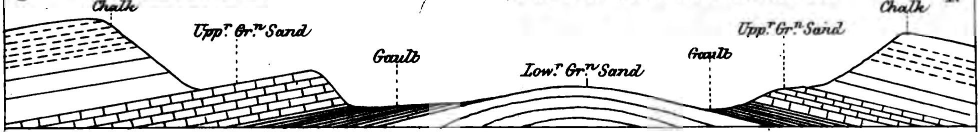
It would, perhaps, be more satisfactory to the reader who may be uninformed upon this interesting subject, if some evidence were adduced of the validity of the last reason here assigned for preferring the hypothesis of the instability of the land to that of a rise and fall in the level of the water. Such changes, then, are actually now in progress upon a large scale, and in one remarkable instance at no very great distance from us. Alterations in the relative height of the land and sea have long been observed in Sweden. The earlier inquirers into this strange fact, more than a century ago, were of opinion that the waters there were gradually subsiding. But proof was subsequently obtained, to the conviction of all those who have inquired into the matter, that the land is, and has been for ages, slowly rising towards the northern end of the Baltic, and sinking, though not at the same rate, towards the south of it. For a long time fishermen and pilots, well acquainted with the coasts of Norway and Sweden, had agreed in declaring that the islands, and rocks, and shoals, with which their daily avocations made them most familiar, were experiencing a gradual change. This prevalent opinion led to the investigation of the matter by properly qualified men of science: the rocks were marked, and after the lapse of a sufficient time re-examined, when the popular conviction proved to be well founded. And it is now universally recognised as an established fact that a tilting of the land is going on there; that while it is rising towards the north, it is sinking towards the south; and that the elevatory movement has amounted in some places to several feet in the course of a century. Other appearances, which of old favoured the notion that the water was diminishing, are evidently corroborative of this conclusion; and prove at the same time that the upheaving force has been active in that region for a long period. Shells of the kinds still inhabiting the Baltic, and the ocean on the opposite side of the country, are found inland in abundance, beginning at the water's edge, and rising to the height of one, two, and even four hundred feet and more above the present sea-level, and extending to a distance of seventy miles from the coast. Under circumstances which have afforded them protection from the destructive influence of the atmosphere, the barnacles still adhere firmly to the upraised rocks, to which they had most certainly affixed themselves when those rocks were beneath the waters of the sea. The upheaval of the land in that quarter is thus made plain, therefore. Very wide tracts of the South American continent have also experienced like upward movements; while the west coast of Greenland, for a distance of more than 600 miles from north to south, has, during some hundreds of years, been losing height. An extensive area of the floor of the South Pacific Ocean is also now sinking. This is made evident by the peculiar construction of the circular coral islands enclosing lagoons so well known there. These owe their singular form to this gradual subsidence, the coral-producing animals, as is their nature, keeping the outer edges of the islands built up to the surface as fast as the bottom of the ocean sinks. Slight changes of elevation caused by earthquake shocks are of such frequent occurrence in various parts of the world that instances need not be adduced. But it is important to recollect that this very usual kind of movement, however small the effect of it might be upon each occasion, if it were repeated at intervals through such

Sections I.II and III.

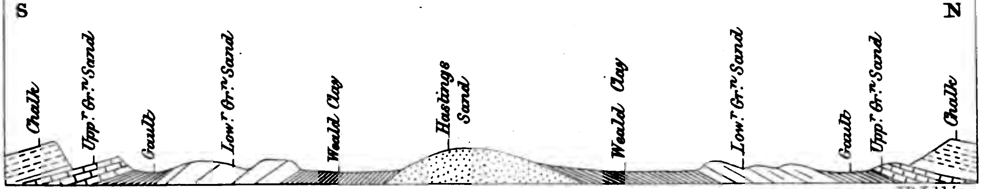
SECTION I. Disturbance of the Chalk near Lewes.



SECTION II. Removal of the Chalk strata west of Petersfield.



SECTION III. Removal of the strata between the North & South Downs.



J.R. Jobbins.

vast periods of time as geology teaches us to contemplate, would be quite sufficient to disturb and fracture the strata, and to raise the surface of a particular region, to almost any extent.[1]

We can have no difficulty, then, in concluding that the chalk has been upheaved from the ocean, amidst the waters of which it was accumulated; for the elevation and depression of the earth's crust may be regarded as happening in the regular course of nature. The curved and dislocated condition of the beds of this particular formation, visible in many places, renders it obvious that it has been subjected to great violence from below. Sir R. I. Murchison speaks of them as exhibiting much contortion, and as being broken up in numerous localities along the range of the South Downs, as though they had been thrown about and shattered by powerful earthquakes.[2] A well-known instance, in the region to which he directs attention, is that of the Coomb, near Lewes. Section I., originally given by Dr. Mantell, will help to explain the nature of such disturbances. The Coomb, *c*, is a narrow ravine, with a flat bottom, ascending between two chalk hills. It is found to coincide with a fault, or line of fracture in the strata, which is in fact the origin of it. While on one side of this chasm the upper and lower chalk, *a b*, maintain their relative position, and are still almost horizontal—as may be seen by the flint courses of the upper chalk—on the opposite side the upper chalk and flints are at the bottom of the hill, and the strata are set nearly on end. Phenomena of this kind speak for themselves.

But it was said that we need not wonder at finding the chalk flints broken and rolled, and removed to great distances from their original position, because it is certain that extensive tracts of the cretaceous formation have been subjected to the erosive power of moving water; and that vast masses of it have been thus worn down, and carried away, to be redeposited wherever they could find a suitable resting place. We cannot have a more striking exemplification of this process than is furnished by the various appearances exhibited in the Weald Valley. (See Map I.) This is a wide extent of country, crossed by the railroad from London to Brighton, surrounded on all sides by chalk hills, except towards the south-east, where, between Dover and Beachy Head, it is bounded by the sea. It comprehends, as has been already mentioned, almost the whole county of Sussex, with parts of Kent, Surrey, and Hampshire. The two ranges of chalk hills called the North and South Downs mark its limits on its northern and southern borders respectively, while sweeping round its western extremity they meet not very far from Petersfield in Hampshire, making the circuit of chalk at that end complete. It is, geologically considered, one valley—a valley of elevation, or denudation; because, being the result of one upward movement, or of a series of such movements, and of the denuding power thus rendered effective, the real rim of the trough is but one, namely, the chalk hills which enclose the whole; but, nevertheless, to the traveller who crosses it from side to side, it presents a succession of hill and dale, the intervening heights being in some instances equal to those of the chalk itself, into the place of which they were thrust up, after the water had washed it away. The Map I., and the Sections II. and III., will perhaps

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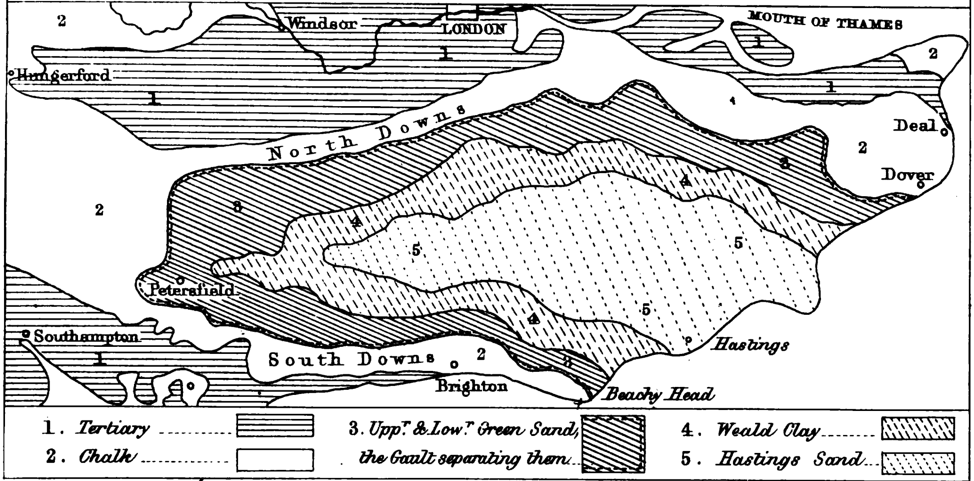
[1] Sir C. Lyell, *Manual*, chap. v. p. 46.

[2] *Quart. Journ.* Geol. Soc. No. 29, p. 370.

Map I.

MAP EXHIBITING THE AREA FROM WHICH THE CHALK HAS BEEN WASHED AWAY IN SUSSEX AND THE ADJOINING COUNTIES.



J.R.Jobbins.

make the geological structure of this remarkable district more intelligible. It will be seen by the Map that the strata 2, 3, and 4, beginning with the chalk (2) of the North Downs near Dover, are continued round in concentric curves until they reach the coast again near Beachy Head, which is the terminating point of the South Downs. This regular arrangement of these several rocks is easily accounted for. They were originally thrown down one upon another as sediment from water, the chalk (2) a marine production—being the top, or newest stratum, while the Hastings Sand (5) deposited first, and from fresh-water, is the oldest, and, of course, the bottom of the whole. Having been thus regularly strewn, in a succession of horizontal layers, the volcanic forces underneath, which have left so many other proofs here as elsewhere of their former activity, upheaved the vast accumulation, which rose in the form of a dome until it came within the influence of the waves on the surface. The strata were then cut off one after the other by the ceaseless motion of the water, the loosened materials being washed away to be dropped again in deeper, and therefore quieter places.[1] By this means the edges of the beds were exposed in a concentric arrangement,—just as would be the case with the coats of an onion from which a slice had been cut,—until the lowest bed—that of the Hastings Sand —escaped from the erosive power, by rising above the waves before they had had time to make so much impression upon it.

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[1] The agitation of the water caused by the wind—the wind wave—reaches to a comparatively small depth only; so that the heavier matter which the sea removes from a coast on which it is preying, generally finds a depth near at hand in which it can again settle itself. If, however, it should come within the influence of a sufficiently powerful ocean current, it may be transported to a much greater distance.

Section II.—from Sir R. I. Murchison,[1]—exhibits the position of the strata at the upper part, or beginning of the Weald Valley, to the west of Petersfield, where it is about four miles wide. A glance at it will be sufficient to convince any one that the several beds, —the chalk, upper green-sand, and gault,—so abruptly cut off on each side, were once continuous across the gap. The erosion here, at its commencement, reached no deeper than to the lower green-sand; but it will be noticed that the strata above that were entirely washed away. As the valley extends towards the east it widens rapidly (as is shown in the Map), the extreme points being forty miles apart; and the lower beds are seen to have been similarly dealt with, as they rose to the surface one after the other.

Section III. exhibits the order in which these severed strata present themselves to the traveller who crosses the Weald Valley from north to south, as he would do between London and Brighton. It happens that they are alternately of hard and soft materials. The consequence of which accidental arrangement is that hill and dale follow each other in regular succession; for the harder rocks, offering the greatest resistance to the dash of the water, would, of course, be left in greater prominence. After gradually ascending for a considerable distance, he will find himself at the top of the North Downs, consisting principally of chalk, the upper part having the usual regular courses of flints. The descent into the valley is rapid, being just such as would be produced by the disintegration, or crumbling down, of a sea-cliff, exposed for ages to the influence of the atmosphere. An upright face of soft chalk, such as it is supposed was left here by the sea, could not stand one winter without yielding a portion of its surface, more or less, to the action of the frost and rain. This matter would find its way to the bottom, and would begin to accumulate at the foot of the precipice. In the course of ages the talus, or slope of loose materials, would rise sufficiently high to reach the upper edge of it, now lowered and rounded down by the same disintegrating causes; and thus the descent from top to bottom would no longer be perpendicular, but at such an angle as was required for the permanent rest of the heap. A process, in some slight degree similar to this, is going forward with great rapidity on the sides of more than one of the railways within twenty miles of London. Wherever the strata are of a soft and yielding nature, the artificial cliffs of the cuttings are sliding down into the hollow; and it is obvious that they will eventually assume the easier slope of the natural hills around them, unless the skill of the engineer should check the mischief.

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[1] *Quart. Journ.* Geol. Soc. No. 29.

After descending this first, and in certain places comparatively abrupt escarpment, in which he will have passed over the edges of the chalk, upper and lower, the chalk marl, and upper green-sand, all of which have a certain degree of hardness, he will find in the valley the softer gault—a bluish clay so called. Gradually rising from this low ground, he will reach the top of the lower green-sand, another hard stratum. Once more a steep descent will bring him down to the Weald clay; from whence he will climb to the summit of the Hastings Sand, and will there stand upon the anticlinal axis[1] of the whole, the several beds that he has already crossed, and the continuance of the same beds, which he will meet with again as he proceeds, all dipping away from him, north and south. In his further progress from this centre he will, of course, pass these beds in reversed order, the steep ascents now facing the north, and the gradual slopes having a southern inclination.

This regular alternation of the softer with the harder materials will account for that remarkable peculiarity in the conformation of this district which consists in the cliff-like character of one side of each of its hills,—the side, namely, which in every instance faces the central axis. While the strata were rising in the form of an arch, as has been already described, the upper unyielding layers of chalk and green-sand must of necessity have cracked, and opened in longitudinal fissures. The water thus admitted to the soft gault clay would quickly wear it away, thus undermining and letting down the superincumbent beds, the scarped ends of which would take the form of cliffs. The ruins of these upper strata being ground down and removed, the same process would be repeated with the beds next in order. The hard lower green-sand, becoming fissured as it rose in its turn, would be undermined by the washing away of the Weald clay under it, and its cliffs, thus let down, and so gradually receding from one another, would at length rise above the waves, as those of the chalk had done before. Lastly, the Hastings Sand would make its appearance, and the water having been now altogether tilted off the surface, the erosion would cease; and the whole region might rise, without any further change than that effected by frost and rain, to its present level.

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[1] A line drawn along a ridge from which the strata dip, or sink, both ways, is called an anticlinal axis.

Whether this process of denudation[1] went on slowly, and was thus the work of ages, as has been here supposed, or whether the same effects were wrought by the sudden upthrow of the bottom of a deep sea, or in some other violent manner, as very eminent geologists think more probable, judging from certain facts which, as it appears to them, are not to be accounted for upon the opposite hypothesis, in the conclusion which affects the present argument all are agreed. No one doubts that the chalk and its flints were once continuous over the whole Weald Valley, or that they were removed from it by water in motion. And thus, from this one district in England alone, about two thousand square miles of materials were washed away, the finer sediment to be borne no one can say how far, the heavier portions, consisting chiefly of flints and sandstones, to be redeposited in the more immediate neighbourhood of their original location. The region then laid bare was, in fact, much larger than this; for a corresponding area of denudation, with its concentric lines of rocks, a counterpart of that in England, may be seen in the opposite coast of France, in the Bas Boulonnais, which seems to indicate that the strata across the whole breadth of the intervening Channel were broken up by the same movement.

It need not be supposed from what has been now said, however, that the Wealden supplied the flints which are dispersed on or near the surface of the counties to the north-east of London. The chalk, as we have seen, is extended along the whole of the north-western border of that district; and there are reasons to convince us that it is to that side we have to look for the origin of these flints, rather than to the chalk south of London. At the same time it may be mentioned, that the Woolwich, Blackheath, and other dense beds of rolled flints which are met with in Kent and Surrey, are supposed to be the result of the denudation of the Weald. These last-named accumulations occupy a geological position removed by a great interval from the formation to be chiefly spoken of here, in which beds of flint-gravel, of a red or yellow colour, abound, and which covers the surface of so great a portion of the eastern counties. The shingle beds at Woolwich and Blackheath, and others connected with them, belong to what is called the Plastic Clay, or Lower Tertiaries, which may be seen in that neighbourhood to pass under the London Clay, and therefore must have been thrown down before it; while the Drift of the eastern counties, with its gravel-beds, reposes upon the top of the latter thick and slowly accumulated deposit, and is thus proved to be more recent than it. There are reasons, indeed, to be mentioned hereafter, which lead with great certainty to the conclusion, that these rolled flints of Kent and Surrey, and those on the surface in Essex, although all alike derived from the chalk, were strewn where they now lie at periods vastly distant from one another.

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[1] The washing away of rocks, whether by the waves or currents of the ocean, or by inundations, or by the slower action of the rain-water on the surface, is called denudation.

What has been said in this chapter affords a fair occasion for a remark or two upon the alleged uncertainty of geological speculations. It has been a favourite argument against this science, urged by those who look at it with suspicion, that its votaries are always disputing among themselves. But the objectors forget that, upon all the more material conclusions with which they are concerned, geologists are quite agreed. How little weight there is in the objection, may be very well shown in connexion with the conflicting hypothesis mentioned above. The dispute is simply this,—Whether it is most in accordance with appearances to conclude that a certain portion of the earth's crust was carried away by a sudden and violent rush of water, such as we have never witnessed, or gradually worn down and removed by the ordinary action of the waves, just as we see the cliffs of our own coasts disappearing at the present moment. In the meantime the disputants on either side are perfectly satisfied,—first, that a vast mass of materials has been washed away from this area; secondly, that it consisted of beds of great thickness, which, for the most part, must have been slowly accumulated; thirdly, that the upper or Chalk strata, so removed, were exclusively marine, while those beneath them, or the Wealden beds, were the deposit of fresh-water; fourthly, that these unquestionable facts indicate several oscillations in the level of this region, since, during the accumulation of beds thrown down by the waters of a river, it must have been for the most part above the sea; during the Chalk Period far below it; while at present the higher parts of its surface are seen to rise to about a thousand feet above the sea-level again; fifthly, that of all the numerous remains of marine and terrestrial animals, preserved here as fossils, whether in the Wealden or Chalk strata, scarcely any, if any, belong to species now in existence; rendering it manifest that there have been successive creations, the older forms having disappeared, to make way for others more nearly approaching those by which we are now surrounded; and, lastly, that this whole collection of records, which may be examined by any one in the archives of nature, refers to a period removed from our own by a great interval of time; as it can be proved that the Chalk had been upheaved, and more or less denuded, before it received upon it the earliest of the Tertiary beds; since which, as must be concluded in all reason, myriads of years, or rather of ages, have passed away, a succession of events requiring so much time having left its marks plainly written in a series of rocks accumulated contemporaneously with those events. If geologists can agree in such important conclusions as these, their disputes about matters of less interest ought not to be urged as bringing discredit upon their favourite pursuit. No one can doubt that there is much scientific truth yet to be discovered; and, until all uncertainties are cleared up, there will be differences of opinion among those who are searching for it.

CHAPTER VI.

By what agency were the chalk-flints distributed?—Not easy to give an account of every bed of gravel—Blackheath and Woolwich shingle beds—Gravel of Thames valley—Drift—the Northern or Boulder Drift—In Norfolk and neighbouring counties—Unbroken flints in Northern Drift—Never been subjected to much violence from moving water—Transported for many miles—Great depression in chalk called London Basin—London Clay—Norfolk Drift resting upon it—How spread?—Dropped by ice-bergs—Two principles for the explanation of such phenomena—Up and down movements of land—Climate by no means always the same in same latitude—Effect of ocean-currents on climate—Effect of position and height of dry land—Ice-bergs now generated as near the equator as the middle of France.

Having shown that the flints of our gravel-pits and surface soil are derived from the Chalk, and that there is abundant evidence to prove that that great formation has been disturbed and broken up, we must next endeavour to ascertain by what agency, and in what manner, these flints were finally distributed, and left in the places in which we now find them.

It is not usually possible to determine all the circumstances under which so casual a deposit as a bed of gravel may have taken up its position. Looking at London as the centre of a district in which this material abounds, we have towards the south and east, at Blackheath and Woolwich, as has been just said, large collections of flint shingle, attaining a thickness of fifty feet and more, perhaps, which seem to have been thrown down there by waves breaking upon a shore which was gradually sinking.[1] The sea at this period was certainly eating away cliffs of upper chalk at no great distance from these accumulations; for in no other manner could such quantities of its peculiar flints have been supplied. These, it is evident, were shattered and rolled by breakers, and then left, one upon the other, until the heaps in some places attained a depth of nearly twenty yards. So thick a mass of pebbles seems to indicate a subsidence of the bottom on which it rested. The waves do not drive up stones above a certain moderate height. But if the land was slowly sinking, relays of flints, washed from the cliffs and rolled on the beach, might have been spread upon the top of those already accumulated as long as the supply lasted, the subsidence regulating in fact the whole operation. In the course of ages an alteration in the underground forces occurred, and the shingle beds were raised altogether above the level of the sea. That such up-and-down movements prevailed there, as everywhere else, there is abundant evidence to prove.

We have again, beginning at Maidenhead and extending for fifty miles from west to east, with a breadth varying from two to nine miles, the gravel-strewn valley of the Thames. It is allowed on all hands that this area presents considerable difficulties to those who are engaged in the disentanglement of its various, and sometimes apparently conflicting, phenomena; but it would be by no means consistent with the object of this book to enter into these discussions, the design of it being to show the reader who is resident in this part of England that he may obtain for himself convincing evidence of two or three simple, but still most important and genetally applicable, geological facts; and to these such difficulties as those now alluded to are in no way whatever opposed. Whether this particular bed of flint-gravel or that was thrown down at this or that particular period, may be a question of the highest interest to the accomplished geologist; but the answer to it, whatever it may be, has no necessary relation to an inquiry into the origin of the stones themselves, of which that gravel is made up, and may have almost as little bearing upon the history of the general deposits of the country round; and this is manifestly the case when the gravel to be considered is that which is met with along the course of a river.

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[1] Lyell, *Man.* 222.

It is not to be doubted that many of the flint-pebbles of the Thames valley—of those that are the most completely rounded especially—have been three times at least beneath salt-water; once when they were formed in their native chalk; once after they had been washed out of the chalk cliffs, and rolled by the breakers on the shore of a sea of another geological age; and again, when that sea-bottom had been in its turn upheaved, and they were brought down by the water of the river, and deposited at its mouth, to be once more elevated with the surface on which we now find them. These facts are sufficiently striking, and they are unquestionable;—but nothing more can be mentioned here than the last operation by which we may suppose a certain portion of these flints were dropped where they now lie. As this region, which had been previously submerged, gradually rose from the sea, every part of the lengthening river must have been in succession an estuary, stretching from side to side of the alluvial plain. Floods would be continually moving down sand and pebbles from the higher ground, where they had been previously left as that ground was raised above the waves, and they would settle themselves in various situations where the river was deeper, and the rush of the water less impetuous. Upon the occasion of heavy rains during a thaw, when large accumulations of snow are quickly melted, the rise of a river is often very great, and the current powerful. Considerable quantities of stones, sand, and silt, frozen to the bottom of the ice which happens to have formed in shallow water, are sometimes transported to great distances, and find their way to the bottom—the coarse and the fine together—without being sorted in the usual manner by the stream which bears them along. Where causes of this uncertain character have been for a long while in operation, their effects must present difficulties to those who seek to account for them. All, therefore, that need be said of the more recent part of the deposits of this valley is, that it is evidently derivable from the basin which the river drains; and that every flint-pebble to be picked up from it bears testimony to the main facts we have to prove. The fossils it contains show that it came from the Chalk, a deep-sea deposit; and it is certain that it was brought down from a region now much above the sea-level. Its journey may have been broken into stages: it may have made halts of longer or shorter continuance on its way: it may have taken its place in more than one stratum since it left its chalky cradle to begin its wanderings; for such may have been the oscillations of the surface during the period it has been on the move, that it may have been, and not improbably has been, over and over again on the sea-shore, to be subjected each time to new violence, and to be borne afterwards to new ground; but we cannot be mistaken in its lineage after all; for that is registered within its own substance in characters as durable as the stone itself; and, strange as the record is, there is scarcely a little garden in the suburbs of London that would not furnish a pebble from which so much could be learned.

But through an extensive district lying to the north of the valley of the Thames, one extremity of which approaches the metropolis while the other reaches the coast of Norfolk, the flints of the surface, and a varied assemblage of other stones with which they are associated, and which have certainly travelled southwards, seem to have been deposited under circumstances which may now be considered to be almost as well ascertained as they are surprising.

There is found spread over almost every country, above the more ancient strata, a superficial covering of clay, sand, and gravel, sometimes sorted and separated into beds, but very frequently with little appearance of any such order. This is called by geologists drift; and is, of course, that part of the earth's crust which most commonly comes under cultivation. Here and there it may have been washed off, and the underlying rocks exposed; but, generally speaking, it maintains its place everywhere. Good instances of drift have been pointed out at Clapham Common, Kensington, and Hyde Park, where the ancient deposit of the London clay is hidden by such beds, which there consist of gravel; while, on the other hand, Primrose Hill has been mentioned as affording an example of denudation, the London clay of that locality having been left without any superstratum whatever. The chalk hills of Hertfordshire, and those near Brighton, present the same contrast, the former being generally covered with a drift of clay, while the latter have only a few inches of loose soil upon them, which has resulted from atmospherical and other causes now in operation, of which more may be said hereafter.[1]

The Northern or Boulder Drift, to which our attention is now to be turned, prevails over a wide area on the eastern side of England. Beginning with an example of it which occurs at Muswell Hill, Highgate, within about five miles of London, it is to be seen spread over many parts of Middlesex, Herts, Bedfordshire, Huntingdonshire, Cambridgeshire, Essex, Suffolk, and Norfolk. In the three latter counties it is very general, one member of it capping, to a depth of from ten to fifty feet, or even more, almost all the hills in the northern division of Essex, and a large portion of Suffolk and Norfolk.[2] From its prevalence in the latter county, and the manner in which its curious and highly interesting curved beds are laid open upon the coast there, especially near Cromer, it is often called the Norfolk Drift. Its mineral ingredients are various: clay, loam, sand, and mixtures of clay and chalk, called in some places clay and in others marl, make up the bulk of the formation, beds of flint-gravel, of greater or less extent, occurring in many parts of it. These latter, from their porous character, and their position, filling up hollows in impermeable beds of clay, often form natural cisterns, which, holding the water up near the surface, and yet preserving it from evaporation, supply the springs and shallow wells of the districts favoured with them.

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[1] Prestwich, *Water-bearing Strata,* p. 19.

[2] Ibid. p. 37.

ery remarkable and characteristic feature of this s found in the number of fragments of rocks of nt kinds, some of large size, rounded and un- d, which have come with it from various and t sources. Mr. Trimmer[1] thus describes the member of it, called the Till, as it is seen in lk:—"It is proved to be a marine deposit by the ells which it contains; but they occur in a nt condition from those of ordinary strata, con- rarely of anything but fragments, distributed he utmost irregularity through the mass, species ferent habits, the inhabitants of sandy and of bottoms, of deep and shallow water, being confusedly together, and associated with frag- of various rocks, often little worn, but much hed,[2] derived from a number of distant places, ixed largely with local detritus. The base h which these fragments of shells and rocks are uted is often not very dissimilar in other respects he London clay. The foreign detritus consists of and pebbles of granite, gneiss, mica-slate, clay- greenstone, porphyry, and other rocks, which no nearer than Scotland or Norway. They con- the tail of a stream of detritus, traceable over e portion of the north of Germany, the blocks shing in size and quantity with their distance Norway and Sweden. Besides these fragments, of Kimmeridge clay and lias are met with, ning their characteristic fossils. Those of the

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[1] *rnal Royal Agricult. Soc.* VII. part 2.

[2] e difference between worn and scratched rocks, and the t treatment which such appearances indicate, will be ed hereafter.

London clay and carboniferous strata are more rare. The most abundant detritus consists of fragmentary chalk and chalk-flints. The till," continues Mr. Trimmer, "is generally said to be unstratified; but improperly as regards that of Norfolk, because, in the least stratified portions, alternations of deposit are marked by irregular seams of fragmentary chalk. In the Upper Drift, however, stratification is much more decided; consisting of beds of sand, gravel, loam, and coarse shingle. The till passes upwards into laminated blue clay and silt, which again pass into the yellow sands of the Upper Drift, containing large masses of fragmentary chalk." This "Boulder Formation," says Sir C. Lyell,[1] "displays almost everywhere a strange heterogeneous mixture of the ruins of adjacent lands, with stones, both angular and rounded, which have come from points often very remote. Thus we find it in our eastern counties containing stones from the Silurian and Carboniferous strata, and from the Lias, Oolite, and Chalk, all with their peculiar fossils, together with trap, syenite, mica-schist, granite, and other crystalline rocks. A fine example of this singular mixture extends to the very suburbs of London, being seen on Muswell Hill, Highgate; but south of London the Northern Drift is wanting; as, for example, in the Wealds of Surrey, Kent, and Sussex."

It is, however, to the flints which abound in this deposit that our attention is to be particularly turned. They here present themselves to our notice in two very different conditions. It will be evident at a glance, in almost any locality, that the greater part of them have been rolled and rounded by moving water (see Fig. 62,

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[1] *Manual*, p. 132.

Pl. XII.), like those of the Blackheath beds and of the Thames valley, and just as similar flints are being still ground down into the same forms upon many parts of our coasts. But there are not a few mingled with them—and some of these stones are weighty—which have no appearance whatever of having suffered any very great attrition. A considerable proportion of them, though not rounded, may be more or less broken; but, taken altogether, there must be a vast number which are as entire as when they were lying quietly in their original chalky bed, their sharp points and multiform protuberances, occasionally so slender as to be easily knocked off by a very slight concussion, being just as perfect as in those which still maintain their position in the chalk strata (see Fig. 63, Pl. XII.).

That these flints have never been subjected to the action of waves breaking on a sea-coast, nor even to the more gentle friction of a flow of water capable of rolling them along its bottom, is very obvious: they could not have been so transported for anything like such distances as we have to account for without showing the effect of such movement, at all events in their more prominent parts: sharp points upon weighty stones could not have remained unworn after such treatment. If these unbroken flints were only seen in small numbers, and near to the chalk from which they were derived, we might imagine that their removal had possibly been effected in this way, though under such circumstances as to leave them in their original condition. But being found where they are, any such conjecture seems inadmissible. Let a person who is travelling through the middle of the county of Essex, little less, perhaps, than twenty miles from any chalk which comes to the surface, look at the flint walls which he may see along the road, and he will be at once convinced of the abundance in which such material must be found, for he may be sure that it is nowhere brought from any great distance. Not only do the gravel pits supply these flints, but continually recurring crops of them are ploughed up from the land, to be picked off for the mending of the roads, or for the use of the builder. Those proper for building are, of course, not large; but many weighty stones have come with them: occasionally one will be found five or six feet in circumference.

It is very true that, at a certain depth—300 or 400 feet perhaps—below the surface upon which these stones rest, chalk is found. But it is no less true that they could not have risen from any such depth; they must, necessarily, have travelled above ground. Essex is included in the basin of London: it stands over the same great depression in the Chalk as the metropolis. A person passing by railway from Reigate in Surrey to Ware in Hertfordshire sees the southern and northern rims of this trough, as the chalk of which it consists rises to the surface near those two places; while its western edge, with that towards the eastern extremity, may be examined if he makes a journey from Hungerford in Berkshire, by Ipswich, to Bury St. Edmunds in Suffolk. This great sunken area in the Chalk, which is several hundred feet below the surface in some places, is filled up with clay and sand, unquestionably carried into it by the waters of the sea, as the marine remains found in many parts of it demonstrate. The lowest member of this deposit—which is indeed the lowest of the Tertiary strata, being that next above the Chalk—is sometimes called the Plastic Clay, because in France, where it was first so named, it supplies a great deal of potter's earth; and sometimes "the Mottled Clays and Sands," which gives a better notion of its prevailing characteristics. The beds next above it, which attain a very considerable thickness, constitute the London Clay Proper. The Plastic Clay lines the chalk-basin throughout; while the London Clay fills up the hollow thus left. This latter, then, is not quite of the same extent as the former, although far more of it is visible: it does not reach from side to side of the chalk depression; but is separated from it by the Plastic Clay, which, resting immediately on the Chalk, rises with it to the surface, and surrounds the London Clay, forming, in fact, an inner basin: so that the traveller, crossing from one side of this district to the other, upon leaving the chalk, passes over first a comparatively narrow strip of Plastic Clay, then many miles of London Clay, and then reaches a strip of Plastic Clay again, before he arrives at the opposite rim of chalk.

Now upon the top of both the one and the other of these formations, spread over the eastern and north-eastern portions of them especially, occurs the Norfolk Drift, a series of irregular beds of clay, sand, and gravel; and it is in this superficial deposit that the unbroken chalk-flints of which we are now speaking occur. There can be no doubt that they have been brought to their present position from the chalk which is everywhere around them; for with them is found a clay mingled with innumerable small rolled fragments of this soft limestone, which could have come from nowhere else. This chalky mixture, or marl, is an excellent manure, and is used by the agriculturist extensively. There is reason to suppose that Essex, and the counties adjoining, have been supplied with this valuable material, and the flints which have come with it, from the north. But the question is, how did they travel in company? It is not, at first sight, easy to say in what manner an almost impalpable substance like fine clay, and ponderous flints, could have been washed over the face of a country ten or twenty miles across, perhaps, and thrown down together in a mass in indiscriminate confusion;—for it is well known that water sorts the materials which it thus removes, dropping the larger masses first, and the smaller and finer in succession, as the current decreases in velocity. A powerful rush of water, capable of bearing away stones of a considerable size, must needs hurry on the clay or mud, which it stirs up with them, to a far greater distance than it carries such weighty bodies. Throughout a depth of many feet of fine clay large stones will be found at intervals, the heaviest of them at the top quite as commonly as at the bottom; and this over an extensive district of a very level character. This, then, is not like the work of any ordinary ocean-current.

It used to be supposed, in the absence of a better hypothesis, that this Drift might be referred to a mighty rush of muddy water, set in motion, somehow or other, from the north; and that it had power enough to hurry along with it, for hundreds of miles, innumerable fragments of rock, vast numbers of them weighing many tons, and some of them hundreds of tons, which it had left scattered over a great part of North America, as well as the North of Europe, England having come in for a certain portion of the strange deposit. It was thought not impossible that an extraordinary stream of this kind might carry forward all this mass of fragments without reference to the form of the country over which it poured, and might drop them, as they are seen to lie, mingled with the finer as well as the coarser matter, and lodged upon the top of hills, as often as in the valleys, and on the plains.

It is manifest, however, that such an hypothesis would but ill account for the phenomenon in its simplest features; and there are facts connected with it for which it would not account at all. The Northern Drift could not have been the result of any such passing torrent; because there are plain signs in various places that its aggregation must have been a work of no inconsiderable time, beds of clay, sand, and gravel, with fragments of stone distributed through them from top to bottom, being often stratified, and resting one upon the other in regular order. And there is another still more striking proof of the gradual heaping up of this remarkable deposit. The fossils which in some places it contains, and in other localities overlies, make it evident beyond all doubt, not only that it was slowly accumulated, but that the process was going on for ages;—beginning in one geological period, it was extended into another. This latter interesting circumstance, however, will be better considered hereafter. It is obvious then, we think, that the drift we have to account for, cannot be referred to sudden violence, or to any transient passage of water.[1]

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[1] It will be understood that nothing now said is meant to apply in any way to the Deluge of the Scriptures. That much more recent event might leave no such trace behind it. So brief an occupation of the surface of the earth by water—and

But there is a carrying power, still busily, though quietly, at work over a considerable part of the globe, which is undoubtedly spreading out deposits in all main respects exactly like that of which we are now speaking. This carrying power is ice; and the whole body of evidence seems to point to a similar agency as the only one that could produce the various appearances which the surface of this district of England presents; they seem plainly referrible to ice-bergs and coast-ice drifting over a sea, and bearing with them, and shooting down as they melted, the loads of stone and dirt which the one had received while it made part of the glacier, and the other had picked up from the bottom of the shallow water in which it was formed, or which had fallen upon it from the overhanging cliff. To the elucidation of this curious subject, the remaining part of this chapter and the whole of the three following will be devoted.

Until persons have examined the proofs upon which such a conclusion is founded, it will no doubt seem to them a startling proposition when it is affirmed that the surface soil upon which they tread may have been dropped down from ice floating in a sea of almost arctic character, beneath which, at that time, a great part of England was submerged. But a little attention to the subject will certainly convince them that this is an hypothesis very far indeed from being extravagant or improbable. In the preceding chapters, be it remem-

possibly only some portion of that surface—might make little or no impression upon it. In the case of a gradual subsidence, and re-elevation of the land,—to which the apparent rise and fall of the water have been referred with great probability—no distinguishing marks might be imprinted.

bered, it has been proved to demonstration that this surface abounds with the fossil remains of marine animals. The gravel walk in the reader's garden, upon which he takes his daily exercise, presents perhaps a pavement—if he resides in the eastern counties most assuredly does present a pavement—the flints of which are full of these fossils. They were formed, therefore, at the bottom of the sea, and most of them were rolled and polished on its shores:—this at least is undeniable. How did they reach the gravel-pit in the adjoining field, so far from the chalk which was their birthplace?

The first step towards the right understanding of the phenomena which are presented to the student of geology, is the conviction that the surface of the earth has, almost everywhere, repeatedly changed its level, so that any particular area may have been at one time lifted up by volcanic forces until it was dry land, a hill, or a lofty mountain, while at another time it may have sunk down to be the floor of an ocean, with thousands of feet of water rolling over it. As there cannot be a reasonable doubt of the prevalence of such oscillations of the surface at all periods, so must they be contemplated as part of the system upon which our globe is ordered.

A second persuasion equally needful for him, and for which the grounds are quite as indisputable, is that climate by no means depends entirely upon latitude, but is greatly modified by other circumstances.

For the establishment of the first of these two principles, enough, perhaps, has been already advanced, and more will be said hereafter: at present we will address ourselves to the consideration of the second.

It is very natural for persons living in England to take it for granted that the temperature of other countries, at an equal distance from the equator, is about the same as their own. The sun is obviously the source of heat, and the intertropical countries have the hottest climates; and it seems to them only reasonable to conclude, that the heat and cold of different regions must needs vary according to their distance from this torrid zone, upon which they know that the rays of the sun fall vertically. And were there no counteracting influences, this would be a safe rule. But in fact the causes of diversity of temperature are so many, that the mere latitude of a place is a very insufficient guide to any conclusion about its climate. Pekin and Lisbon, both in the northern hemisphere, are nearly on the same parallel of latitude; but while, in the latter, the heat of summer is generally moderate, and the winter so mild that an extra garment—a cloak—serves instead of a fire; in the former, the scorching rays of the summer sun exceed those of Cairo, in Africa, and the winter is as rigorous as that of Upsala, in Sweden.[1] New York, again, is as nearly as may be in the latitude of Naples. But the contrast of their winter climates is very striking. In Naples it is seldom as cold as it is in the north of England in September, and vegetation is never interrupted. In the middle of winter the fields are green, the orange-trees in blossom, and the balmy air is filled with the fragrance of blooming shrubs and flowers. At New York, on the contrary, the cold season begins to make itself felt by the end of October, and by the shortest day has set in completely; from which time, for six or seven weeks, the winter is very severe, the thermometer standing for several days, perhaps, some degrees below zero. At Philadelphia, yet two degrees nearer the equator than New York, and in the same latitude as Valencia in Spain—at which place even slight hoar frost is very uncommon—the cold of winter is so piercing that, notwithstanding the motion of the water, caused by the great rise and fall of the tide, the Delaware, a river a mile in breadth, is often frozen over in twenty-four hours; and it continues in that state from twenty to forty days.

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[1] Sir C. Lyell, *Princip.* I. 165.

But, if we extend our view to places on the opposite sides of the equator, though still at the same distance from it—which, if latitude alone governed the temperature, should have the same climate—we shall find a still more surprising difference. The island of South Georgia, in the southern hemisphere, is as near to the equator as Yorkshire, on our side of the globe. There Captain Cook found the snow, which never disappears, coming down to the level of the sea. Neither tree nor shrub enlivened the desolate prospect: a few tufts of grass and moss, scantily covering some of the rocks, from which the snow was melted by the summer's sun, was the only verdure. It is to be recollected that the lands here compared are both insular, and, therefore, in that main respect at least, exactly similarly circumstanced. Yet while on the one the loftiest heights are only snow-clad in the coldest weather of the winter months, the other has an arctic covering in its warmest season. The mountains of Scotland, which are four degrees farther from the equator than is South Georgia, do not reach the line of perpetual snow, even at an altitude of nearly five thousand feet; but on the inhospitable shores of the latter, the snow and salt-spray are said to be for ever in near neighbourhood: at all events, the glacier-ice descends to the sea-level.[1] It is abundantly evident, therefore, that latitude is by no means the only matter into which we have to inquire when we are endeavouring to account for the heat or cold of a country.

There are many circumstances, as has been already said, which may give rise to great diversities of climate in places which are at the same distance from the equator. Of these, the most influential are found to be ocean currents, and the extent and position, as well as the height, of the land. Now it must be apparent at first sight that, if the earth's crust has been subject in times past to great up and down movements, so as to have altered the direction of these currents, the relative proportions of sea and land, and, as has assuredly been the case, the height and position of the latter, the whole surface of the terraqueous globe may have varied to so great an extent as to have caused vast alterations of temperature in certain latitudes.

The most remarkable ocean-current with which geographers are acquainted, is that known as the Gulf Stream. In this immense river of warm water we in England are specially interested, as the climate of our island, which is much milder than might have been expected from its mere latitude, seems to be materially influenced by it. It is well known that a great current sets from the coast of Africa across the Atlantic Ocean to the Caribbean Sea, whence it passes on into the Gulf of Mexico, where the water acquires a very high temperature, as much as seven degrees above that of the Atlantic in the same latitude. Issuing thence through the Straits of Florida, with a velocity of four miles an hour, it flows northward in a stream more than seventy miles broad, and at least two hundred feet deep. It then bends round to the west, and crosses the Atlantic back again to the neighbourhood of the Azores, where it spreads out over a space from two to three hundred miles wide, and is from seven to ten degrees warmer than the waters of the surrounding ocean.—"The heat of this great body of water is kept up by the incessant and quick arrivals of fresh supplies from the south; and there can be no doubt that the general climate of parts of Europe and America is materially affected by this cause."[1] "Were it not for this unceasing current from tropical seas," says Mr. Prestwich,[2] "London, instead of its present moderate average winter temperature of six degrees above the freezing point, might for many months annually be ice-bound by a settled cold of from ten to thirty degrees below that point, and have its pleasant summer months replaced by a season so short as not to allow corn to ripen, and only an Alpine vegetation to flourish."—So far, therefore, is it from being difficult to believe that the climate of this part of the globe was ever so cold as to have given occasion to glaciers and ice-bergs, that we cannot but look upon its present temperature as the exceptional case; since our mild winters are plainly owing to so accidental a circumstance as that of our being within the influence of this great flow of warm water.[3]

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[1] Sir C. Lyell, *Princip.* I. 189.

It is, indeed, by no means certain that the Gulf Stream has pursued the course just described for more than a comparatively brief space of time. It can be proved that the North American continent has been submerged to a very great extent at a recent geological period. And it has been thought that this current would of necessity have then found its way from the Gulf of Mexico along what is now the Valley of the Mississippi—at that time a great arm of the sea—and so would have gone in a straight line to the Arctic Regions; and that, having arrived there, it must have tended to increase the volume of the cold counter-current which, then as now, would flow from those icy regions southwards. It is argued that, in this manner, the temperature of the waters surrounding the British Isles must have been greatly lowered in two ways; first, through the failure of the warm stream; and then by the flow of the gelid current from the north.[1] Whether or not the pent-up water of the Gulf of Mexico ever found vent in that direction may be uncertain; but it is sufficient for our present argument to have shown that such a diversion of its course is possible; and that if it ever obtained, the result must have been a vast increase of cold in the region of Great Britain.

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[1] Sir C. Lyell, *Princip.* I. 167.

[2] *The Ground beneath Us*, p. 20.

[3] Ibid. p. 19.

Still more influential upon climate than even ocean currents, are the position and the height of the dry land. It is found by observation all over the globe, that land which is continuous from regions of great cold has a much lower temperature in the same latitude than that which is separated from such chilling contact by an intervening ocean. Thus, Lapland, although twelve degrees farther north, has a more temperate climate than the south of Greenland; because the one is continued towards the pole, while the other is cut off from it by the Arctic Ocean. And the cold of such a country will of course increase in proportion to its elevation above the sea-level. A great increase of very high land stretching from either of the poles towards the equator would, therefore, have prodigious influence in lowering the general temperature all over the world; for no such change can take place in any one part of it, without being felt in due proportion in every other part. But if such an augmentation of the extent of the land, together with an increase in the height of that already existing there, should chance to occur in the Arctic and Antarctic regions at the same time, it might give occasion to a general degree of cold to which it would not be very easy to assign limits.[1] Now, since it is incontrovertibly established that a great portion of the present dry land of the earth was under water at a comparatively late period of our planet's history, and that parts of that formerly submerged area are now ten thousand feet above the sea-level, it cannot be considered an improbable conjecture that, at that time, an equal extent of land now submerged was elevated to a like height; and it might have been so placed, in or near the polar regions, as to have given rise to a degree of cold abundantly sufficient to have generated glaciers in our latitude, which might have descended, even from mountains of moderate height, to the level of the sea, and have covered its surface with floating ice.

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[1] Mr. Hopkins, *Quart. Journ.* Geol. Soc. Vol. viii. part i.

We must always recollect that it is most satisfactorily proved, by means of the various fossils imbedded in the strata, that there have been in the course of ages a succession of climates—hot, cold, and temperate—within the very same area,—that of our own island, for instance; and that such a strange vicissitude of temperature must be somehow or other accounted for. Now if this region had passed from a hot climate to a cold one gradually, a moderate temperature intervening, it might be supposed that such a change was the result of the slow cooling down of our globe from a former state of greater heat: and this has been a favourite hypothesis. But such a regular diminution of heat is not consistent with the facts before us. The area of which we are speaking has certainly experienced, even since the commencement of the Tertiary period, the series of changes just indicated. For ages together it must have had a high temperature; then a very low one; and now it has a climate between the extremes. And there seems to be no way of accounting for these alternations so legitimate, or so probable, as by supposing that there was a general prevalence of low tropical lands during the period of heat, and of lofty arctic lands while the cold obtained; the medium, or present temperature, resulting, of course, from a certain proportion of each. That land within the tropics is as influential in the general diffusion of heat, as is land near the poles in the abstraction of it, is certainly known. Africa at this moment acts, as has been well said, like a great furnace, distributing heat, by means of aërial currents, far and wide.

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[1] Sir C. Lyell, *Princip.* I. 190.

But in the case before us we have little occasion to speculate upon possibilities, or to imagine a state of things which may be thought unlikely to have existed. Sea-borne ice, in a lower latitude than England, is at this moment doing all that we suppose it to have done here when the Northern Drift was deposited,—that is, during the Glacial Period, as it is called,—the cold of which seems certainly to have prevailed over this part of the globe very recently. On the western coast of the southern half of South America, beginning at a point nearer by two degrees to the equator, or to the hottest part of the earth, than is England, numerous glaciers descend to the sea; and their extremities, as is usual under such circumstances, being from time to time detached from the parent mass, float away, in great numbers, as ice-bergs, carrying with them abundance of stones and dirt, to be shot down wherever they happen to melt. The whole of that coast is being gradually upheaved by earthquake shocks; and should the adjoining floor of the Pacific be ever exposed, as seems not improbable, it will be found covered with a deposit in essential characters like the Drift of which we are speaking; it will be seen to consist of clay, sand, and gravel, in much confusion, and containing, through its whole thickness from top to bottom, blocks of stone of all the various kinds supplied by the several valleys down which the glaciers take their course. Already there is enough of this sea-bottom sufficiently upraised to admit of examination, and this is precisely the nature of the stratum there being heaped together.

Now it is to be particularly noted that all this is the consequence of the peculiar distribution and height of the land towards the south pole, and other conditions just as liable to variation. A region as near to the equator as the middle of France, is now sending off, from every suitable opening along an extensive line of coast, numerous ice-bergs, such as there appears good reason to suppose formerly floated over a great part of what is now England. It is obvious, therefore, that there can be no objection, from any consideration of latitude or climate, to this mode of accounting for that deposit which we see under our feet, the character of which points in so remarkable a manner to a similar origin. The greater part of England, and much of Europe, was certainly covered with salt-water during the time in which the Northern Drift was thrown down. It is highly probable that land now submerged was then elevated above the sea. Let us only suppose, as is very reasonable, that the situation of that land was such as would give occasion to a considerable, though by no means an unlikely, degree of cold in the region with which we are concerned, and we have at once before us a conjunction of circumstances which would naturally produce the singular accumulation which we are considering. "I have endeavoured, in the Principles of Geology, Chapters 7 and 8," says Sir C. Lyell,[1] "to point out the intimate connexion of climate and the physical geography of the globe, and the dependence of the mean annual temperature, not only on the height of the dry land, but on its distribution in high or low latitudes at particular epochs. If, for example, at certain periods of the past, the antarctic land was less elevated and less extensive than now, while that at the north pole was higher and more continuous, the conditions of the northern and southern hemispheres might have been the reverse of what we now witness in regard to climate, although the mountains of Scandinavia, Scotland, and Switzerland may have been less elevated than at present. But if in both of the polar regions a considerable area of elevated dry land existed, such a concurrence of refrigerating conditions in both hemispheres might have created for a time an intensity of cold never experienced since; and such probably was the state of things during this period."

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[1] *Manual*, p. 146.

But it will be asked whether, in addition to the peculiar character of this Boulder Drift, we have or have not other proof that such cold did prevail, and produce glaciers reaching the sea in this part of the globe at the period of which we are speaking; that is, either immediately before the time when England assumed, for the most part, its present form and general level, or during the movements by which that form and height above the sea were acquired.

That the needful cold did formerly obtain in this region, generating glaciers in favourable places, there cannot be a doubt; and that these glaciers descended to the sea, and were the origin of numerous ice-bergs which, with the ice-rafts formed on the neighbouring coasts, bore away and deposited on the sea bottom, their usual loads of stones and dirt, is almost as little to be questioned. But as the discussion of this interesting subject will occupy some little space, it will be as well to devote to it a separate chapter.

CHAPTER VII.

Glaciers—Formerly in British Islands—If instrumental in distributing drift must have descended to sea-level—Wide area over which ice-bergs are now distributing drift—Several kinds of ice-bergs—Which distribute drift in both hemispheres in lower latitudes than England—Much of British Isles under water at period of Norfolk Drift—With glaciers reaching the sea—Stones and drift scored and scratched as if by glaciers—Great cold prevailed at the period of the Norfolk Drift—New and interesting corroboration of this fact.

Most persons, perhaps, have a general notion of a glacier. When a mountain is so high that its upper part is covered all the year round with snow, elongated masses, or, as it were, rivers of ice in a peculiar state, supplied from this unfailing storehouse, descend such ravines and valleys as are suitable for their formation. They are the result of the alternate thaw of summer and frost of winter; and find their way down very slowly by their own weight, in a sort of partially fluid or viscous state, much as a mixture of flour and water, or dough, if of the proper consistence, might creep down the board on which it rested, if tilted at the required slope.

But although, in such vast accumulations, the ice is pliable enough to move in this manner, it is nevertheless so hard as to bear upon its surface, and carry down with it those heaps of stony fragments and dirt, which, detached by frost and rain, fall from the rocks by which it is skirted. This rubbish naturally forms two lines, one on each side of the glacier; and they are accordingly called its lateral moraines; while the continually growing collection which is shot down at its end, where the warmer air of a lower region melts the ice, is the terminal moraine.

Now in consequence of the unceasing downward movement of the weighty mass, and the perennial supply of stones from above to act as gravers—for some of them drop in, and grate along between the embankment and the ice, while others are frozen hard into its substance, and stand out from it in various positions, and not a few fall through the deep clefts, or *crevasses*, which open on its surface, and so find their way to the rock beneath—a glacier leaves such marks upon the sides and bottom of the trough along which it travels, as would prove beyond a doubt its former presence, should the temperature of the region so alter as to become unfitted for its longer continuance there. The hard and enduring surface of rock with which it is in contact, partly smoothed, and sometimes even polished, is moreover scored and grooved in such deeply cut and often parallel lines, which dip wherever the sliding mass sinks into a depression, or rise, as, driven by the weight behind, it is forced up by some obstruction in its course, that the channel thus characteristically sculptured on its floor and sides, must tell for ages of the singular stream which once found its way along it.

In the British Islands there are at present no glaciers. Our mountains are not high enough; for they none of them reach the elevation at which, with the average temperature prevailing here at this time, the snow remains unmelted the year round. But there are many rocky valleys radiating from the summits of our higher hills, which show clearly enough that they were once occupied by glaciers. M. Agassiz, one of the best authorities on such subjects, has pointed out Ben Nevis in the north of Scotland, and the Grampians in the south, as indicating, by the blocks of stone deposited down the sides of their valleys, the former existence there of glaciers, which have left these lines of fragments as plain traces of their moraines. He found evidence of the same kind among the heights of Northumberland, Westmoreland, and Cumberland, of Wales, and of Antrim, Wicklow, and the west of Ireland. Dr. Buckland, an authority entitled to equal respect, mentions other localities which afford similar evidence of the same thing. He directs attention to the peculiar rounded bosses of rock—prominences which have been rounded off by attrition—and polished surfaces, often accompanied by grooves and scratches, which, familiar to the eye of every explorer of the Alps, he attributes to glacier action—in the valleys of the Conway, the Llugwy, the Ogwyn, and the Sciant, and of Llanberis and other places in North Wales. Mr. C. Darwin, whose reputation is not inferior to either of the distinguished geologists already mentioned, adduces other instances of the same kind from the country round London, Professor Ramsey agreeing with him in his views. But of all the writers upon glaciers, no one has studied them more carefully or more successfully than Professor James Forbes. In his "Notes on the Topography and Geology of the Cuchullen Hills in the Isle of Skye, and the Traces of Ancient Glaciers which they present," he "points out groovings and scratchings upon polished rocks of a marked kind," says Sir H. De la Bêche, to whose "Geological Observer"[1] we are indebted for most of this information. He observes respecting the valley of Coruisk, that "the surfaces of hypersthene" (a volcanic rock), "thus planed or evened, present systems of grooves exactly similar to those so much insisted on in the action of existing glaciers on subjacent rocks, and as evidence of glaciers in parts of the Alps and Jura, where they are at present wanting." "These grooves," he says, "are as well marked, as continuous, and as strictly parallel to what I have elsewhere shown to be the necessary course of a tenacious mass of ice urged by gravity down a valley, as anywhere in the Alps." He then tells us that they occur among the hills of Skye in high vertical cliffs, just as they do near the Pissevache; that they rise here against opposing promontories, as they do in the valley of Hasli; that they make deep channels or flutings in the trough of the valley, as at Pont Pelissier near Chamouni, and as at Fee in the valley of Saas; that, at the same time, these appearances have a superior limit,—as in the present glacier valleys the markings reach only a certain definite height,—above which the craggy angular forms are almost exclusively seen, where the phenomena of wearing and grooving entirely disappear. "In short," concludes Professor Forbes, "it would be quite impossible to find, in the Alps or elsewhere, these phenomena —except only the high polish which the rocks here do not admit of—in greater perfection than in the valley of Coruisk."

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[1] Page 311.

Such evidence as this, and much more of the same tendency might be adduced, has left no doubt upon the minds of these competent judges that, during a former, though, geologically speaking, late period, many of the higher hills of Great Britain and Ireland were furnished with their glaciers, which, for a lengthened series of years, worked their natural effects, precisely as similar accumulations of ice, in various parts of the world, are at this day producing like results under the same circumstances.

But an ordinary inland glacier—such as the well-known Mer de Glace, near Chamouni, the end of which does not reach the sea-level within thousands of feet, because the temperature of the lower regions there is too high to allow any such extension of the ice—would distribute no stones and dirt beyond the immediate valley which it occupies, except the mud and smaller fragments which the always attending glacier-river might have power to carry down with it. If the ice which has left its marks in the ravines and valleys of our mountains was ever instrumental in the distribution of mineral matter, such as the Boulder Drift of which we are speaking, over the surface of this country—over our midland and eastern counties, for instance, as there is abundant reason to think it did—it must have been at a time when it found its way down to the sea, and furnished a supply of ice-bergs to be driven with their freight of stones and mud, whichever way the wind or ocean currents might chance to propel them, across these regions then submerged. The same process must have gone on within the area now occupied by the British Islands, as arctic voyagers witness in many places on the western side of Greenland. There, every valley which comes down to the coast being occupied by its glacier, and every such glacier reaching the sea, fleets of ice-bergs—which are nothing more than the detached lower ends of these frozen streams—are continually floating away to shoot down the detritus with which they are burdened wherever they go to pieces or melt. Amidst the stillness of those solitudes, nothing is more striking, we are told, than the loud reports, resembling the discharge of heavy ordnance, which are heard from time to time as some of even the smaller masses of ice, breaking from the parent glacier, fall into the water. The formation of a sea-bottom, which may hereafter be upheaved in a condition fit for the support of vegetable and animal life, seems to be the chief operation in which nature is engaged under such circumstances.

It is of much importance in this inquiry to recollect the extent of the area over which, in one part or other of the world, the floor of the sea is at this moment receiving a deposit of mud, sand, gravel, and rocky fragments, which is being dropped down upon it in this manner; and to consider the conditions under which that operation is proceeding. The ice-rafts which carry out this detritus are of three different kinds. There is, first, the ice-berg properly so called—*iis-berg* or mountain of ice, thus named originally, it is probable, by the Dutch navigators. It is, as has been already said, the offspring of the glacier. Its majestic appearance, with its serrated crest, or lofty pinnacles rising high into the air, is familiar to most persons from the plates in books of Arctic discovery. It brings out with it whatever trains of fragments and dirt may have fallen upon it in its slow descent down the glacier valley, of which it bears not uncommonly a very considerable load, some of the stones being occasionally of very large size. The second kind of raft is that which is supplied by such fields of ice as that of the great barrier of the antarctic regions.[1] This vast sheet of frozen snow and water, which skirts the shores of that inhospitable region for an unknown distance, presents to those approaching it the appearance of a lofty cliff, quite flat at the top, with a perpendicular face rising to one hundred and fifty or two hundred feet above the sea, the water, for a considerable distance in front of it, being covered with floating fragments, great and small, which have been broken off from it. It is of immense thickness. Sir James Ross saw detached portions of it, sixty miles from its edge, which were fast aground where the water was 1,560 feet deep; what height they stood above the surface is not mentioned. This wonderful field of ice is seen to be traversed by great cracks; and whenever there are considerable changes of temperature, huge sheets—occasionally many miles in length—separate from the main body, and float out to sea. "Though from its general mode of occurrence," says Sir H. De la Bêche,[2] "the great icy barrier of the antarctic regions might not, at first, appear any important agent in the transportal of mineral matter, it has been found that, under certain conditions, portions of the ice, detached from it, may bear no inconsiderable amount of mud, sand, and rock fragments of various sizes into milder climates, depositing their loads over the bottom of the sea upon which they may be carried." The third kind of ice-raft is that which is supplied by ordinary coast ice. Wherever the temperature is sufficiently low, the shallow water on the sea-brink in favourable situations will freeze. This, therefore, is a very widely prevailing source of supply for smaller floes;

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[1] *Geological Observer*, p. 267. [2] Ibid.

ough they are often large enough to bear away masses stone of no mean weight; and are, for the most rt, laden besides with pebbles, sand, and mud, picked from the bottom with which they have been in conct. We may judge of the aggregate effect which even is minor operation of nature would work out in the urse of ages, by what it is known to have accomplished a comparatively brief space of time in the Baltic. he current which flows from that sea through the attegat carries out in the spring much coast ice. In 44 a diver found the remains of an English cutter, own up during the bombardment of Copenhagen not ty years before, covered with blocks of stone, some which measured from six to eight cubic feet. The me man affirmed that all the wrecks to which he had scended in the roadstead of Copenhagen were more less laden with the same kind of fragments.[1] It uld seem very probable, and well agreeing with these ts, that the lighter matter, mud and sand, which st have been thrown down with such stones, had en carried onward by the stream to a greater distance, ving in that submarine valley just such trains of ighty erratic boulders as are met with in the ancient ift for which we are endeavouring to account.

Starting, then, from the various centres of dispersion, ence drift is being strewn over the sea-floor, these ee kinds of ice-rafts bear their burdens over a large a, both in the northern and southern regions of the be. Greenland is a land of glaciers. Along its tern, as well as its western coast, the current setting the southward brings down the ice-bergs, which that ole country supplies, to hold on their course as far as the temperature of the sea and air, or casualties of one kind or other, may permit. This icy stream is by no means of very limited extent. Occasionally, it is so broad on the eastern side of Greenland as to reach the coast of Iceland; and the accumulation of fragments at Cape Farewell sometimes stretches out into the sea to a distance of one hundred and sixty miles. The main body of these floating bergs, joined by those from Davis's Straits, makes its way along the American shore to Newfoundland. But many of them reach to much more southerly points. M. Couthouy mentions an ice-berg, with apparently boulders upon it, as low down as latitude 36° 10″ north, and longitude 39° west,[1] that is in the middle of the Atlantic, about opposite to the entrance of the Mediterranean. But, not to lay too much stress upon extreme cases, it may be said without hesitation that, in our own hemisphere, in the same latitude as Great Britain, and over a surface vastly larger than that of the British Isles, a drift like that of Norfolk is, at this moment, being deposited from floating ice. If we pass next to the regions of the extreme south, we shall find nature there equally busy in the same important work. A vast extent of sea is traversed by the ice-bergs furnished by the glaciers of the Antarctic lands. Sir James Ross mentions a great glacier at Ætna Islet, South Shetland, as descending from a height of 1,250 feet into the ocean, where it presented a vertical cliff of 100 feet. Adjoining the termination of the glacier he found the largest aggregation of icebergs, evidently broken from it, he had ever seen collected together.[2] Glaciers in other parts are pointed out on the same authority. But this is eminently the region of the great icy barrier; and from its far-stretching cliffs innumerable tabular ice islands are detached.[1] With vertical sides, and a flat top—which is so smooth that it looks like a sheet of frosted silver—and often of almost incredible size, they make their way to a warmer climate by sailing northward; and so scatter the *dêbris* they carry over the bottom of that part of the Pacific Ocean. Sir James Ross met with many of them in about 63° south, still raising their tabular summits 120 or even 180 feet above the surface of the sea, several of them exceeding two miles in circumference. But they have frequently a more northerly range than this by ten or twelve degrees; and so great was their number in the year 1832, that vessels bound round Cape Horn from the Pacific, were obliged to put back to Chili for a time, in order to avoid them.[2]

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[1] *Geological Observer*, p. 285.

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[1] *Geological Observer*, p. 265.

[2] Ibid. p. 266.

We could well suppose, that masses of ice of such a vast thickness as those which have been now mentioned —for they must have from six to eight feet below the water, for every foot above it—might reach the latitudes named before they had fallen to pieces; although it must not be forgotten that those latitudes are as far from the South Pole as England is from the North. But, as has been already observed, it is, at first sight, very surprising that glaciers reaching the sea are generated, and ice-bergs in great numbers are detached from them, in a latitude which corresponds in one hemisphere with France in the other. No glacier in the Alps descends within several thousand feet of the sea-level; but on the western coast of South America they reach the sea in even a lower latitude;[3] and from the island of Chiloe southward to Terra del Fuego, they supply a great deal of floating ice. But this cold climate, in a country six degrees nearer the equator than England, is, nevertheless, easily accounted for. It is obviously caused by the great height and consequent extreme cold of the Antarctic lands, by the current of cold water which sets from the icy region against that coast, and by the ice floating about those seas, which chills the air, and causes continual fogs, by means of which the influence of the sun's rays is greatly lessened.

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[1] *Geological Observer*, p. 270.

[2] Ibid. p. 275.

[3] Sir C. Lyell, *Manual*, p. 151.

Now it is particularly worthy of note that all these conditions might have belonged to England at the Drift period, the latitude being more favourable for them. Certain it is, that a boulder drift with all its peculiarities is being deposited by floating ice in the south as well as in the north, in a region as near to the equator as England is. And—to repeat what was said above—should this end of America continue to rise as it has done from time to time, which is very probable, and the Antarctic lands sink, which, as they are volcanic, cannot be deemed improbable,[1] there would come into existence, with a climate more or less like ours, a drift-covered country, showing all the marks of former glaciers, with scored and polished rock surfaces,[2] and doubtless with its superficial covering in some places left in the confusion in which it was thrown down, in others sorted and stratified by partial currents. In particular localities the grounding of ice-bergs may have driven up the sand and mud into heaps, and contorted and crushed it into a variety of unaccountable flexures, just as our drift is seen on the coast of Norfolk, as will hereafter be described. To glacial

[1] See *Geol. Observer*, p. 290.

[2] Sir C. Lyell, *Manual*, 151.

operations, then, similar to those now pointed out, there is, so far, good reason to suppose that a considerable part of the surface of England owes its origin.

There can be no doubt, at all events, that, at the period of which we are speaking, the greater part of the land which is now the British Islands was covered with sea-water; and, in the neighbourhood of our higher mountains, was so deeply submerged that glaciers, of which there are abundant evidences to be seen there, did reach the sea.[1]

The proofs of the submergence of this whole area, at that time, to a considerable depth—in some places to the extent of nearly 1,400 feet—seem to be absolutely incontrovertible. We may begin with the east side of England, where it is least observable. In 1829, Sir C. Lyell[2] made a particular examination of the cliffs of eastern Norfolk; and he tells us that near Hasborough he found the descending section as follows: 1st. sand and loam, thirteen feet; 2dly, unstratified mud, or, as that confused formation is called, till, from eight to sixteen feet; 3rdly, laminated sand and clay, one foot and a half, part of the clay being bituminous—of course, from the vegetable matter present—and inclosing compressed branches and leaves of trees. The entire height of this cliff was thirty-five feet; but he subsequently found the same remains under an accumulation of similar strata of double that thickness. Here, then, we have proof of a subsidence of the land to the depth of seventy feet. These branches and leaves of trees, as we shall see, marked the site of an ancient forest, with its bed of mould, which, since the time when this terrestrial vegetation sprang from it, must needs have been depressed to at least the whole of this extent, most probably very much lower, or a deposit of that thickness, thrown down gradually from water, could not have accumulated over it. Upon the interesting subject of this "submarine forest of East Norfolk" much has been written: we extract the following particulars from Sir C. Lyell's paper in the magazine already referred to. Mr. R. C. Taylor observes of this deposit generally, that, "It consists, in some places, of forest peat, containing fir cones and fragments of bones; in others of woody clay; and elsewhere of large stools of trees standing thickly together, the stems appearing to have been broken off about eighteen inches from their base. They are evidently rooted in the clay or sandy bed in which they originally grew, and their stems, branches, and leaves lie around them, flattened by the pressure of from thirty to three hundred feet of diluvial deposits." "At Paling," says the Rev. James Layton, "the stumps of the trees seem now to be really standing: the roots are spread abroad, and intermingling with each other; were a torrent to sweep away the mould from the surface of a thick wood, leaving the roots bare in the ground, the appearances would be exactly the same." "About this stratum are found numerous remains of mammalia, the horns and bones of at least four kinds of deer, &c. These fossils are found at Hasborough and its neighbourhood on the denuded clay shore: at Mundesley they are found in the cliff." Mr. Simeon Simons of Cromer states that, at Cromer, he saw ten or more trees, in the space of half an acre, exposed below the cliffs eastward of that town, the stumps being a few inches, or all less than a foot, in height, some of them no less than nine or ten feet in girth, the roots spreading from them on all sides throughout a space twenty feet in diameter." "The great extent of this submerged forest," observes Sir C. Lyell, "is proved, not only by the numerous points at which it appears between Paling and Runton—which are about twenty miles apart, reckoning by the sea-coast, and nearly as far in a direct line—but also by the proofs afforded of its extension inland in proportion as the overlying beds are swept away by denudation;" which here, it may be added, is constantly going on.

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[1] *Geological Observer*, pp. 300, 312.

[2] Lond. and Edinbr. *Phil. Mag.* May, 1840.

It appears, then, that there is conclusive evidence of a downward movement of the land on the east coast of England, to the depth of 300 feet;[1] and that this depression had taken place just previously to the deposition of the Norfolk Drift, or was still going on while that deposit was being thrown down. There can be no misapprehension in this case. A diluvial accumulation of 300 feet, gradually heaped up above the remains of terrestrial vegetation, which still maintains the position in which it grew, with its roots yet fixed in the soil, speaks unmistakably of a depression of the ancient land, to the whole depth of that accumulation at the very least; for in no other manner is it possible to account for the phenomena: the trees must have grown there when the surface of the land was above the sea-level.

If we move westward, we shall find in the counties more in the middle of the island, proofs of subsidence at this period to a still greater amount.[2] A drift, or superficial deposit, upon the top of the more ancient formations, with its fragments of stone rolled and unrolled—just such an accumulation as glacier ice leaves

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[1] Mr. Trimmer says 600 feet. *Journ.* Royl. Agric. Soc. vol. vii. part 2.

[2] Sir C. Lyell, *Manual*, p. 137.

—may be observed in the counties of Lancashire, Cheshire, Shropshire, Staffordshire, and Worcestershire; and it furnishes specimens of marine shells, of species now living, which are to be seen sometimes at an elevation of 350 feet above the sea-level. The boulders which are distributed through this drift, and which give no bad evidence that they must have been dropped here by ice, are to be referred, it appears, partly to the mountains of Cumberland, and partly to those of Scotland, their mineral character declaring their parentage, as it is to those parts of our island we must go for rocks of a like kind. And it will not be forgotten that we have already seen that among the heights in those same regions are unequivocal marks of glacier action. Here, then, we have 350 feet of depression.

It is to be noted, that we are now looking for proof of a subsidence of the land, to a certain, comparatively speaking, moderate amount, at the period when the drift of Norfolk was deposited. Nothing would be easier than to show, that the part of the earth's crust on which we dwell has, at one time or other, experienced movements upon a vastly grander scale than that with which we are now concerned. During the time that the Carboniferous, Devonian, and inferior strata, which are exposed in Wales and the adjoining parts of England, were accumulating, the original floor of the ocean on which they were successively deposited must have sunk very many thousand feet. "The downward movement was very gradual," says Sir C. Lyell, "and a maximum thickness of 32,000 feet"—more than six miles—"of rock was formed, whilst the bed of the sea was all the time continuously and tranquilly subsiding."[1] The greater

[1] *Manual,* p. 65.

part of the coal seams owe their origin to terrestrial vegetation, which grew upon the very soil—the underclay, as it is called by miners—on which the bituminous matter still rests. They must, therefore, have been at one time upon a surface which was, upon the whole, raised above the water; for nowhere else could some of these plants have flourished. But their mineralized remains are now covered, in some places, by thousands of feet of sandstone, clayshale, and other earthy matter, thrown down upon them by water, as the stratum which supported them sank to a lower level; and in many instances they are, at this moment, continued under the sea. Such a proof of great downward movement is absolutely incontestible; it is as conclusive as is the evidence of a like upheaval which is furnished by various mountain masses, filled from top to bottom with the remains of marine animals. But the proofs of a subsidence of the land, during the drift period, to such an extent as would bring down to the sea-level those of our valleys which exhibit the marks of having been worn by glacier action, although sufficient, are not of this striking kind. We have seen that shells, of species now living, are found in the drift in the middle of England, at the height of 350 feet above the sea. Mr. Darwin, directing attention to the blocks of stone from distant localities which are scattered over the midland counties, has pointed out a large greenstone boulder, seemingly from Wales, upon Ashley Heath, in Staffordshire, at an altitude of 803 feet.[1] This marks, of course, a former subsidence to something very considerably more than that extent; for most certainly the sea was the means of its transport, and an ice-raft the only conceivable buoy; and if so, there must have been some depth of water to float it, since ice, without any additional burden of stones, requires it. The same competent judge infers from other data, that Scotland was at that time submerged to a depth of at least 1,300 feet. But Mr. Trimmer has made evident a greater depression still. He discovered this peculiar formation, the Northern Drift, with the marine fossils which here and there accompany it, at the height of very nearly 1,400 feet, upon Moel Tryfane, a mountain near the Menai Straits, in North Wales; thus demonstrating the fact of this subsidence at the proper geological period, and on the very spot required to make good our present argument; for among the adjoining Snowdonian mountains are some of the glacier valleys, whence, as is concluded, a part of those ice-bergs issued which distributed a portion of this deposit over the submerged surface of our island; and a stratum lodged at an altitude of 1,400 feet must afford good evidence, as was just now said, of a depression of greater amount. It is of this district Mr. Darwin is speaking, where he says,[1] "We have the clearest proofs of the existence of glaciers in this country; and it appears that, when the land stood at a lower level, some of them, as at Nant Francon, reached the sea, where ice-bergs charged with fragments would occasionally be found. By this means, we may suppose, the great angular blocks of Welsh rocks, scattered over the central counties of England, were transported."

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[1] *Geological Observer*, p. 311.

Scotland affords evidence of a like submergence as conclusive in its character as this of Wales.[2] Here these erratics, or travelled blocks, have been oftentimes carried over the country to the south of their parent rocks, in such a manner as to show that their course was not in the least affected by the hills or valleys which intervened. This proves that they were borne along by some carrying power which was independent of such irregularities of surface. Had a rush of water been the means of their transport, they would not have been left upon the side of a hill, as many of the largest of them are, quite as often as they found their way to the bottom of the valleys: there would have been some proof, at all events, of their having been sorted according to their size: the stream must have dropped those first that were the most ponderous—but this is not so. The Grampian mountains rise to the height of 3,000 feet and more. Between that range and the Sidlaw hills, which are to the south of it, is the great valley of Strathmore. Across this deep depression, for a distance of fifteen miles, huge fragments of rocks, some of them fifteen feet in diameter, have been carried, to be lodged on the very summit of the opposite heights, at least 1,500 feet above the level of the sea, while others are scattered over the low country which is intermediate. There can be no mistake as to the original of these blocks; for they are of the same mica-schist as is found in the Grampians, while their present resting places, the Sidlaw hills, are of sandstone and shale. Still farther south, upon the Pentland hills, may be seen a mass of mica-schist, weighing from eight to ten tons, at an altitude of 1,100 feet above the sea. This huge fragment must have travelled fifty miles, as there are no rocks of the kind within that distance.

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[1] *Geological Observer*, p. 312. [2] Sir C. Lyell, *Manual*, p. 131.

Sir H. De la Bêche, in his "Geological Observer,"[1] has given a map of the land which would remain above the water, supposing the British Isles were depressed a thousand feet below the level at which they now stand. "And it should be noticed," he says, "that of a submergence to this, and even a greater amount, at a comparatively recent geological period, there would appear to be good evidence." The whole of Great Britain was then represented by three or four groups, or rather, perhaps, a chain, of islands (see Map II.), five of some little extent—though none of these equalled in size our largest English county, Yorkshire—while the others ranged from an area somewhat larger than that of Anglesea, to a mere speck in the water. But no conformation of the dry land could be more favourable for the supply of ice-borne fragments than the one thus presented to us. Only let it be shown that the climate of these mountainous islands was such as is required for the formation of glaciers in valleys reaching the sea, and it would need no stretch of the imagination to picture the surrounding water as teeming with rafts so laden.

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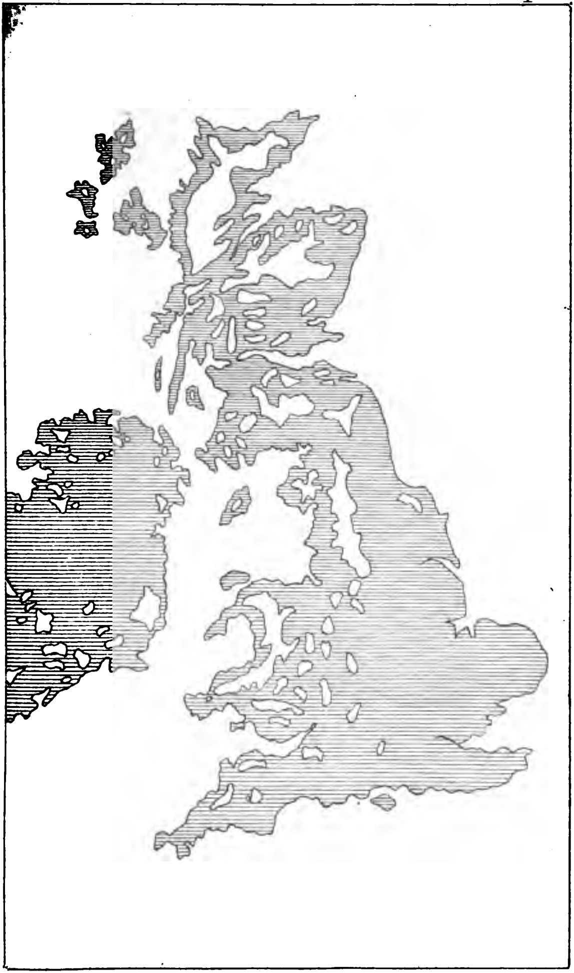
[1] Page 301.

Now we have seen that the heaping together of a very recent formation—the Boulder Drift—was contemporary with a depression of the land. And it can be proved, by evidence which shall be considered presently, that this drift was accumulated during the prevalence of a degree of cold, considerably greater than that which is at this day experienced within the same area. This depression of the land then—and consequently a sea studded over with islands in the place of Great Britain—was also contemporaneous with that prevalence of cold. It is highly probable, therefore, that the glacier markings, the grooves, and striæ, and smoothed surfaces, which are so conspicuous in some of

Map II.



J.R.Jobbins.

the valleys of Wales, the north of England, and Scotland, are likewise to be ascribed to that period. For, as it cannot be doubted that they were produced by ice, so it is only reasonable to refer them to the most recent time in which the needful cold is likely to have been found there; since scratches upon exposed surfaces of rock cannot last for ever, inasmuch as the hardest stone yields by degrees to atmospherical influences.

But that the drift and these island glaciers were really connected, another, and, as it should seem, satisfactory proof may be offered. The stones and grit which are frozen into glacier-ice score and scratch the sides and bottom of the glacier valley. These stones, as a matter of course, are scored and scratched in turn. The waves of the sea roll the stones which are brought within their influence, rounding off their angles, and smoothing the surface; but glacier action often leaves one side flat, with parallel lines cut into it. Wherever, then, glacier fragments present themselves in an unrolled condition, there striated blocks may be looked for. Doubtless there are multitudes of stones which have once borne such marks, from which subsequent rolling by moving water has obliterated them. But others would escape such rough treatment, so as still to tell the history of their former life. The drift, then, affords these characteristic stones in quite as great abundance as could have been expected. The fragments of rock in the Norfolk Drift, says Mr. Trimmer, are, "often little waterworn, but much scratched."[1] "It is by no means rare," Sir C. Lyell tells us, "to meet with boulders imbedded in drift which are worn flat on one or more of their sides, the surface being at the same time polished, furrowed, and striated."[1] These marked stones point directly and distinctly to glacial action. And since, as in the engraving on the die and the head on the medal, the scored rock and the striated boulder bear mutual testimony to a relationship between them, it is scarcely to be doubted that glaciers occupying the valleys of islands, under the circumstances which have been pointed out, supplied a portion of the drift of our eastern counties. The presence of chalk flints among it has already been partly accounted for; and their special means of transport will be considered hereafter.

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[1] *Journ.* Roy. Agri. Soc. vol. vii. part 2, p. 461.

But it is desirable that we should understand the grounds on which it is concluded that the period here spoken of was one of considerable cold. The conchologist, then, is quite competent to pronounce upon the general temperature of any region which furnishes him with a pretty full collection of its shells. The drift, it is true, is not prolific in fossils: it is only here and there that it yields shells; but, wherever they appear, they have a very decidedly northern aspect: as a group they belong to a colder region than that in which they are now found.[2] It may be safely laid down as a general rule that, in proportion to the greater degree of cold in the seas which they inhabit, the number of different species of mollusks will be smaller: there may be a great abundance of individual shells, but no great variety of kinds. It is in the more genial climates that nature is lavish of form and colour. Our own seas at this moment are not distinguished either for the number of species, or for the beauty of the shells which they produce. But the late Professor Edward Forbes—the highest authority upon such a subject—has shown that the boulder deposit in Scotland, Ireland, and England makes it sufficiently manifest that, at that period, the number of different species of shells was greatly smaller in the seas beneath which it was accumulated than they are known to be at present in the British seas; and that the homely shells of a more arctic climate were those which were most abundant, and most widely spread, through the whole of the drift from north to south.

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[1] *Manual,* p. 143.

[2] Sir C. Lyell, *Manual,* p. 132.

The argument in support of the conclusion that a rigorous climate obtained in this part of the world at the period when this deposit was being thrown down has lately received a very interesting confirmation.[1] The formations which in England precede the Norfolk drift are, in the descending order, the Norwich, Red, and Coralline Crags. Recent investigations have enabled geologists to prove that, during the time when these several strata were accumulating, the climate was gradually changing from a warm to a cold one. Sir C. Lyell[2] has given some tables, framed from Mr. Searles Wood's "Monograph on the Crag and Upper Tertiary Shells of Britain," by which it appears that while the Coralline Crag yields 327 species of shells, and the Red Crag, which is next above it, 225, the Norwich Crag, which is immediately below the Drift, and so, as it were, introduces it, furnishes no more than eighty-one species. These facts, according to the rule already laid down, would of themselves afford good reason for believing that, from some cause or other, a much lower temperature prevailed during the period represented by the latter than by the former accumulations. But, in truth, these three groups of shells give evidence in support of this conclusion of a kind still more direct. While of the recent species of shells found in the lowest of these Crags there are not two in a hundred which are at this day peculiar to latitudes more to the north than England, and in the middle deposit there are about six per cent. only, in the upper, or Norwich Crag, which came immediately before the Drift, the northern species increase in number to more than seventeen per cent. Nor does any such statement of the increasing number of northern forms, though very expressive, give the full value of the evidence adduced. "It is," says Sir C. Lyell,[1] "the predominance of certain genera and species which satisfies the mind of a conchologist as to the arctic character of the Norwich Crag." And he thus sums up on the facts which were before him to that time—1857. "In conclusion, it may be observed that the cold, which had gone on increasing from the time of the Coralline to that of the Norwich Crag, continued, though not perhaps without some oscillations of temperature, to become more and more severe after the accumulation of the latter, until it reached its maximum in what has been called the Glacial epoch. The marine fauna of this last period contains, both in Ireland and Scotland, recent species of mollusca now living in Greenland and other seas far north of the areas where we find their remains in a fossil state."

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[1] Sir C. Lyell, *Supplement to Manual*, 1858.

[2] Ibid. p. 5.

There are yet other phenomena connected with the drift which still lead to the conviction that it is a glacial deposit; and we must trespass on the reader's patience while we pass them under review. But it will be more convenient to consider them in another chapter.

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[1] Sir C. Lyell, *Supplement to Manual*, p. 5.

CHAPTER VIII.

Further proofs of glacial action at period of Boulder Drift—Scoring of rocks beneath Drift—Rounding of pinnacles of rock—Chalk too soft to retain such marks—But Drift much disturbed, probably by means of ice—Ice-bergs of present day displacing drift—Flints of eastern counties dropped by coast-ice.

It is well known that much the larger part of every ice-berg, as it floats, is beneath the water. In each particular instance, the proportion of the one part to the other will depend more or less upon the comparative solidity of the mass, since it may be of a compact texture or the reverse; and also upon the quantity of heavy material, stones and dirt, which it may chance to carry; for it must not be forgotten that such detritus may be mixed up with the ice through a great part of its substance, and, if so, would sink it considerably lower in the water than if it were free from such additional weight. But, approximately speaking, there are six, and occasionally eight times as much ice under the water as is visible above it. Now, as there is often a thickness of from one to two hundred feet exposed—that is, the height of an ordinary, or of a lofty church steeple—there must be from six to sixteen hundred feet out of sight. The consequence is, that ice-bergs frequently run aground, especially as they approach a coast. It is easy to conceive that, under these circumstances, having been urged along by the wind in one direction for hundreds of miles, perhaps, the momentum they acquire must be immense, not a few of them being several miles in circumference.[1] Many of those carefully measured by the officers of a late exploring expedition were from two to five miles in length, and one was seen that was ascertained to be thirteen miles long. When, with all this enormous force, they strike and grate along the floor of the sea, if it should chance to be rocky, they smooth and polish it, at the same time cutting deep furrows and grooves upon its surface, often in parallel lines, by means of the fragments of stone which happen to be scattered about, or which they carry with them frozen into the lower part of their mass.

Now the Boulder Drift in many parts of the northern hemisphere—for it is by no means confined to our islands—rests upon hard rocks of granite, gneiss, marble, and other stone, which, when protected from the disintegrating influences of the atmosphere, are capable of retaining permanently such marks when once they have been made upon them,[2] and it is found that they afford abundant evidence of having been subjected to this grinding and scoring process; they present a smoothed or a polished surface, with scratches and parallel flutings, which often extend for a long way together in the same direction. This is what might be expected, from the great size of the ice-bergs; as, when once fully in motion, such huge floats would hold on in the same course without being turned from it by minor impediments, or any small amount of friction. If, on the contrary, it be supposed that these marks were left by stony fragments driven over the face of the rocks by some powerful rush of water, it will be difficult to

[1] Sir C. Lyell, *Manual*, 128.

[2] Ibid. 127.

account for their very frequent persistence in a straight line; since blocks of stone of such a size as are usually seen in juxtaposition with these marks, if merely so whirled along, would be every moment liable to be turned aside by any irregularity of bottom.

The travelled boulders, and fragments of rocks which are scattered over such scored surfaces, and the shells which are occasionally associated with them, prove clearly that the whole has risen from beneath the waters.[1] If we suppose, as the facts seem to indicate very plainly, that there was first a subsidence of the land, and that this operation was a slow one, similar to that which is at this moment going on in Greenland, there will be no difficulty in accounting either for the wide extent of this phenomenon, or for the circumstance of the marked surfaces being covered almost everywhere with drift, subsequently thrown down upon them. As the land was being gradually let down by volcanic influences, at work at, perhaps, an immense depth underneath, every portion of it, as it descended below the sea level, would be successively subjected to the action of the floating masses of ice, to be scored or smoothed according to circumstances. At length, however, it would be depressed to such a depth as to be no longer within reach of this kind of violence; and then it would be gradually covered up with the materials, stones and dirt, which might be disengaged from the melting ice floating about in the sea above. When the whole was again upheaved, the appearances would be in all respects such as are now observed. But a great lapse of time would seem to be required to account for the general prevalence of these striated surfaces: it does not seem probable, scarcely possible, that they could have resulted from any transient rush of water, however much laden the wave might be with stones, or however rapid its motion. "No flood of water, however violent, or however great the quantity of detritus, or size of the rocky fragments swept along by it, could produce," says Sir C. Lyell,[1] "such long, perfectly straight and parallel furrows, as are everywhere visible in the Niagara district, and generally in the region north of the fortieth parallel of latitude."

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[1] Sir C. Lyell, *Manual*, 142.

And the same observation will equally apply to another phenomenon which has been noticed in connexion with the drift.[2] Whether the current which brought these boulders was a permanent ocean stream, like that which sets southward through Davis's Straits,[3] and is every day doing the same work, by floating down heavily-laden ice-bergs from the west coast of Greenland; or whether it depended upon a prevailing wind; or whatever might be the propelling power, it is certain that it was from the north. Now it appears that, in Norway and other parts, such pinnacles and abruptly terminating ridges of rock as face the north are smoothed and scored on that exposed front, while on the south, or side turned away, and so protected from such attrition, they exhibit no such appearances; but that here, instead, are heaped up unrolled fragments, boulders and gravel, just such débris, in short, as was likely to be collected together where, under the lee of these buttresses, some of the ice-floes might remain stationary, to melt, and so deposit their loads. The same natural operation is going on now wherever

[1] *Manual*, 142.

[2] Ibid. 129.

[3] Lord Dufferin's "Letters from High Latitudes," p. 263.

the conditions of the various agents are suitable. “M. Frapolli,” says Sir H. De la Bêche, “calls attention to the effects of coast ice armed with blocks and pebbles of rock, driven about in numerous fragments by the storms of winter and spring, and grinding against the cliffs of Scandinavia, polishing and scratching the rocks, according to their surfaces and position; the cliffs being scratched in horizontal lines along the fiords, and in other similar positions.”

That some pinnacles of rock might, under peculiarly favourable circumstances, have been rounded, polished, and scored by a passing torrent, hurrying along with it, in great abundance, stones of all sizes, may, no doubt, be possible; that such memorials of sudden violence should be left, as frequently occurring features in a country, by any wave of that kind, seems scarcely probable; like the grooving of the rocky floor beneath the drift, it must be supposed to have been the work of ages, when, year after year, for many centuries together it may be, a relative level of sea and land, a suitable climate, and other conditions, not now existing, perhaps, in the same parts of the world, combined in affording all the means required for the production of such phenomena.

The drift which contains chalk flints in Norfolk, Suffolk, Essex, and the neighbouring counties—with which we are more particularly concerned—rests on no surface harder than the chalk; and it cannot, therefore, be shown, by precisely such evidence as has just been glanced at—the polishing and grooving of the rocks beneath it, for instance—that it was deposited by melting ice. But it agrees so entirely, in its main charac-

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[1] *Geol. Observer*, p. 283.

teristics, with those portions of the formation which are found in localities that do afford these proofs, that there can scarcely be a doubt as to the identity of the carrying power which left them both where they now rest. The mere circumstance that the one as well as the other is remarkable for a heterogeneous assemblage of travelled blocks, indiscriminately mixed up with it, evidently from very different sources and distances, occurring as often on or near the surface as lower down in it, and in juxtaposition with the finest, as commonly as with the coarser detritus, points very significantly, as has been already shown, to some mode of transport by which the sorting power of moving water was avoided in both cases alike. And it has been seen that, in the one case, there is good proof, from the "written rocks" beneath it, that floating ice was the means of conveyance. Still the drift of our eastern counties, laid open to observation for many miles where the sea is undermining and removing the cliffs on both sides of Cromer in Norfolk, displays so great an amount, and such a peculiarity of derangement, as seems not easily accounted for in any other manner than by supposing it to have been subjected to the action of ice-bergs which, taking the ground amid the deposit, crushed and drove it in heaps before them, while it was in a loose and incoherent state. Sir C. Lyell, having made this matter a subject of special inquiry, has thus given us his thoughts upon it in the last edition of his Manual.[1] After pointing out that the chalk bottom, and the layers of the drift immediately above it, have not been disturbed, while the strata over these have been strangely displaced and contorted, he says, "We are called upon, then, to explain how any force can have been exerted against the upper masses, so as to produce movements in which the subjacent strata have not participated. It may be answered, that if we conceive the Till and its boulders to have been drifted to their present place by ice, the lateral pressure may have been supplied by the stranding of ice-islands. We learn from Messrs. Dease and Simpson, that in the polar regions, such islands, when they run aground, push before them large mounds of shingle and sand. It is, therefore, probable that they often cause great alterations in the arrangement of pliant and incoherent strata forming the upper part of shoals or submerged banks, the inferior portions of the same remaining unmoved. Or, many of the complicated curvatures of these layers of loose sand and gravel may have been due to another cause, the melting on the spot of ice-bergs and coast ice in which successive deposits of pebbles, sand, ice, snow, and mud, together with huge masses of rock fallen from cliffs, may have become interstratified. Ice-islands so constituted often capsize when afloat, and gravel, once horizontal, may have assumed, before the associated ice was melted, an inclined or vertical position. The packing of ice forced upon a coast may lead to similar derangement in a frozen conglomerate of sand and shingle; and, as Mr. Trimmer has suggested, alternate layers of earthy matter may have sunk down slowly during the liquefaction of the intercalated ice, so as to assume the most fantastic and anomalous positions, while the strata below, and those afterwards thrown down above, may be perfectly horizontal."

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[1] Page 136.

"There is, however, still another mode," continues the same high authority, "in which some of these bendings may have been produced. When a railway embankment is thrown across a marsh, or across the bed of a drained lake, we frequently find that the foundation, consisting of peat and shell-marl, or of quicksand and mud, gives way, and sinks as fast as the embankment is raised on the top. At the same time, there is often seen at the distance of many yards, in some neighbouring part of the morass, a squeezing up of pliant strata, the amount of upheaval depending on the volume and weight of materials heaped upon the embankment. In 1852, I saw a remarkable instance of such a downward and lateral pressure, in the suburbs of Boston, U.S., near the South Cove. With a view of converting part of an estuary overflowed at high tide into dry land, they had thrown into it a vast load of stones and sand, upwards of 900,000 cubic yards in volume. Under this weight the mud had sunk down many yards vertically. Meanwhile the adjoining bottom of the estuary, supporting a dense growth of salt-water plants, only visible at low tide, had been pushed gradually upward, in the course of many months, so as to project five or six feet above high-water mark. The upraised mass was bent into five or six anticlinal folds, and below the upper layer of turf, consisting of salt-marsh plants, mud was seen above the level of high tide, full of sea shells. In some of these beds the layers of shells were quite vertical. The upraised area was seventy-five feet wide, and several hundred yards long. Were an equal load, melted out of ice-bergs or coast ice, thrown down on the floor of a sea, consisting of soft mud and sand, similar disturbances and contortions might result in some adjacent pliant strata, yet the underlying more solid rocks might remain undisturbed; and newer formations, perfectly horizontal, might be afterwards superimposed."

It will be observed by the reader that, whichever of these hypotheses may be adopted as the most probable, still ice is the agent, in part or altogether, by which the effects are supposed to have been produced; and there is no reason why the several forces may not all have been in operation at the same time.

That such displacements in strata, which might otherwise have been horizontal, are being wrought at this present time where ice-bergs are driven upon a bottom of soft mud, is certain. In the paragraph quoted above, Sir C. Lyell refers to a remarkable instance of this kind which came under the observation of Messrs. Dease and Simpson. He had called attention to it fifteen years ago with somewhat more particularity. "In the account given of their recent arctic discoveries," he says, "we learn that, in latitude about seventy-one degrees north, longitude one hundred and fifty-six degrees west, they found a long low spit, named Point Barrow, composed of gravel and loose sand, in some parts more than a quarter of a mile broad, which the pressure of the ice had forced up into numerous mounds, that, viewed from a distance, assumed the appearance of large boulder rocks."[1] He adds that so many proofs have come to his knowledge of the manner in which masses of ice, even of moderate size, in the Baltic, and still more in the Gulf of St. Lawrence, push before them large heaps of boulders, that he cannot doubt that considerable flexure and dislocation are so produced under favouring circumstances.

The observations of Sir H. De la Bêche upon this whole subject must not be passed over.[1] "The northern ice-bergs," he says, "must be regarded as the great carriers of rock fragments, often of great size, from the lands where the bergs have been formed as portions of glaciers, over a part of the Northern Atlantic, distributing them upon the bottom in various directions, and upon parts of it to which no other cause now contributes detritus. Blocks and minor fragments may even be thus dropped upon bare rocks beneath, and upon every kind of inequality. Should a constant supply of block-bearing ice-bergs, regarding the subject generally, be thrown into any constant current, corresponding lines of deposit would result, assuming the melting of masses of ice, of various sizes, at different times and distances during their progress in such current; these lines having no reference to the form of the bottom, or its modifications from any other deposits accumulated now, or at previous geological times. Stranded near shores, or upon mud or sand-banks, these, though somewhat deep in the sea, catching their submerged portions, ice-bergs would tend much to disturb detrital deposits beneath them, particularly when moved by the waves produced during heavy gales of wind, as also by the rise and fall of tides. The heavy thumping of such huge masses, as some of these ice-bergs are, would cause great derangement of deposits effected tranquilly; and, in many situations, blocks and fragments of rock, with gravels, sands, and clays, would be irregularly mixed by the application of such force—singular intermixtures, and contortions of any previously bedded structure being produced. The ice-bergs which ground upon the banks of Newfoundland can scarcely fail to produce much disturbance of the bottom, often adding to it great blocks and minor fragments of rocks, borne by them from more northern regions." "Mr. Couthouy, in the 'American Journal of Science,'" he adds, "mentions having seen, in September, 1822, a large ice-berg aground on the eastern edge of the Great Bank of Newfoundland, and considered to be in about 720 feet of water, the soundings three miles inside giving 630 feet. A fresh wind from the eastward kept forcing it on the bank, the sea causing it to rock with a heavy grinding noise. On another occasion, August, 1827, he observed another ice-berg aground upon the Great Bank, in between 480 and 520 feet water. The huge mass rocked with the swell going at the time, and even turned half over when struck by the breakers. The sea, for about a quarter of a mile round, was discoloured by mud, worked up from beneath. Above water, the ice-berg was 50 to 70 feet high, and about 1,200 feet long. It suddenly fell over on its side, with much disturbance of the sea."

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[1] Lond. and Edinbr. *Phil. Mag.* No. 104.

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[1] *Geological Observer*, p. 265.

Facts of this kind need little comment: everybody must at once perceive their bearing upon such a question as the one now before us. Let us suppose, for a moment, that the last-mentioned ice-berg, having taken the ground completely, and become fixed, had slowly melted on the spot, and that the sea-bottom, which had been subjected to the process just described, had afterwards been upheaved. We could hardly conceive a more accurate counterpart of the contorted beds of the Norfolk Drift than the one which might thus be presented to us. The strata under this ice-berg, upon which it had been forced—and it was by no means an unusually large one, we should remember—must have been strangely displaced by such violent treatment, as the discoloured sea around it sufficiently indicated. On either side of such a breakwater would probably have run a strong current, sorting the disturbed materials which came under its influence, and arranging them in beds of some regularity according to their size. In front of it there would be a mound, of confused sand and gravel, perhaps, pushed up by the ice-berg as it was forced on the bank by the wind; and this would be covered with a deposit of the finer matter, which had settled in the quieter water. Above the whole might be more or less spread out, or might sink down without much derangement, the detritus, large and small, which would be gradually disengaged from the melting mass. Here, then, would be in juxtaposition a heterogeneous mixture of materials in the utmost confusion, and beds of gravel, sand, and clay, without any peculiar rush of water, or unusual wave of any kind.

While upon this subject we may take the opportunity of saying a few words upon the means by which, as seems likely, the flints were deposited in the beds of drift in our eastern counties. It has already been mentioned, that the chalk formation which supplies them reaches the surface along the whole of the northern and western boundaries of this district. The ice-stream, as we have seen, came from that quarter, and so ran in the right direction to bring them. It is not necessary to suppose, however, that glacier-ice, or ice-bergs properly so called, were the means of their transport. None of our chalk hills were ever high enough, it may be, for the production of glaciers;[1] but wherever chalk made part of the coast of the glacial sea, ice-floes might form upon the shores, and under the cliffs, and, whenever there was a covering of clay and sand upon the chalk, might pick up just such materials as are found in the marl and clay pits of Essex,—a mixture of chalk and siliceous matter, in varying proportions, with flints of all sizes, rolled and unrolled, distributed, irrespectively of their weight, through the whole.

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[1] *Geological Observer*, p. 312.

The carrying away by such coast ice of detritus which, when shot down upon the sea-bottom, would have all the character of the Drift, is an operation that may be witnessed at the present moment in many parts of the world. Even heavy fragments of stone may be thus deposited in deep water. "A good example of the removal of a block of rock by coast ice, so far from the polar regions as Denmark," says Sir H. De la Bêche,[1] "is mentioned by Dr. Forchammer; who states that one, about four or five tons in weight, was encased in coast ice during the winter of 1844, and carried out to sea with the ice in the following spring, leaving, as it moved seaward, a deep furrow in the sandy clay of the shore, not quite obliterated six months afterwards." We may safely conjecture that no small freight of this sand and clay was picked up by such a floe as it froze in contact with them; and that, whenever the ice had so far melted that its buoyancy was no longer equal to the load it carried, the whole would sink down together, to leave on the bottom a confused deposit, unless the various materials chanced to be more or less completely sorted and stratified, as they found there a current fitted to produce such an effect.

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[1] *Geological Observer*, p. 285.

CHAPTER IX.

Boulder Drift occurs on Continent of Europe—and in North America—Strata in various countries how known to be of same age—Four tests—Superposition—Mineral character—Fossils—Included fragments—Northern Drift of several countries proved to be of same age by fossils—Boulder Drift of North of Europe—Of United States and Canada—No boulder drift in equatorial regions where ice is wanting—Boulder Drift of Alps—Such drift everywhere associated with glacial phenomena—Therefore the result of glacial action.

WHAT has been hitherto said upon the subject of the Northern Drift, applies chiefly to that extensive formation as it appears in our islands. But the subject would be hardly placed before those who are otherwise unacquainted with it in so prominent a point of view as its great interest demands, if nothing more were here said of its prevalence, and mode of occurrence, in the North of Europe and North America. There, in two different quarters of the world, over wide-spread regions, a deposit, perfectly similar in its leading characteristics to that of England, was thrown down contemporaneously with it, and it cannot be doubted by the same agency.

But before we go further it may be as well to explain, rather more fully than we have done, how it is known that strata found in countries so far separated from one another are of the same age, that is, were deposited at about the same time.

There are several tests, then, by which the relative age of water-strewn beds of materials may be determined:[1]—namely, 1st, superposition; 2ndly, mineral character; 3rdly, fossils, or organic remains; and 4thly, included fragments. I. The use of the first of these tests is obvious. Where strata have remained undisturbed, the uppermost of the series was, of course, the last thrown down, and is the newest; while that which is lowest, as is equally evident, must be the oldest of the whole. II. The mineral composition of beds is no absolute test of relative age; because the same ingredients being deposited under similar circumstances, the same kind of rock would be the result; and this may of course happen at any time. But, practically, this means of discrimination is of great use to the geologist, as it is found that a recurrence in the series of two rocks exactly alike in mineral character is not very common. III. Animals and vegetables, of which fossils are the remains, are, as most persons know, separated by natural distinctions into genera and species. The wolf is of the same genus as the fox, and the apple is of the same genus as the pear; but in either case the species is different. Under the same head, or genus, many different species may be included: the sloe, the cherry, the apricot, and the two well-known evergreens, the common laurel and the Portugal laurel, are all plums: they are of different species, but not of different genera: they are related to one another by many common characters; but they are severed by specific peculiarities. Now it has been established beyond all doubt that, just as individual animals and plants have died, so entire species and genera of both the one and the other have passed away. And it has never happened that, having thus come to an end, they have reappeared. Other genera and species have been created to take their place, and keep the earth's ever varying surface suitably furnished; but when once a species or a genus has arrived at the end of its life, as it may be called, that same kind has never been called into being again. The consequence of this general law by which the Great Creator is pleased to act is, that from the lowest depths upwards, the strata, in which are entombed the relics of all this variety of animal and vegetable life, are for the most part easily distinguished from each other. No palæontologist could look at three groups of fossils collected respectively from the Primary, Secondary, and Tertiary strata, and doubt for a moment from which of those three great divisions of the earth's crust each assemblage came, so entirely would they differ the one from the other. And this same test is equally valuable for the discriminating of the beds into which these greater divisions may be severally subdivided. Thus the Lias and the Chalk are two formations—the former from near the bottom, the latter from the top—of the same, that is of the Secondary series; yet fair selections of the prevailing organic remains from the Lias and the Chalk respectively, would be marked by such a variety of forms peculiar to each, that the proper place of the beds which produced them could be unfailingly assigned. It is a well-known and most apt illustration of the value of fossils in thus determining the relative age of the strata, to liken them to coins struck at different periods. As these fix the date of events occurring in the history of mankind, so those establish the chronological position of the various groups in the succession of living organisms; and they are therefore called *the medals of creation*. IV. Included fragments constitute the last test to be mentioned. The earth's crust, as we have seen, has been, and still is, subjected to movements from beneath, by which a fossil-bearing stratum, formed at the bottom of the water, may be upheaved to become part of an island or continent, whose cliffs, worn away by the waves, may go to make up a new bed in the sea adjoining. If this deposit should ever be upraised, a single enclosed fragment which contained fossils peculiar to the prior formation, would at once fix the relative age of the two beds.

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[1] Sir C. Lyell, *Manual*, p. 98.

To prove that the Boulder Drift strata of the North of Europe, North America, and the British Isles, were in the course of deposition at the same time, the third only of these tests need be applied: that fact is established by the fossils they contain.

Organic remains, as we have already said, are by no means common in the Drift. There may be many which have been washed into it from earlier formations—as, for instance, the flint fossils from the Chalk; but those which properly belong to it have been found but in few places. Their scarcity has been referred to the prevalence of cold at that period, and to the probability that the shallower parts of the sea might be freshened by the melting of numerous ice-bergs. The fish in the fiords of Norway are sometimes thus destroyed, and famine has been caused among the people of Iceland by the stranding of ice-bergs on its coast, which have not only so chilled the air as to interfere with their hay-harvest, but have also rendered their sea unproductive by cooling and freshening its waters.[1] The few fossils, however, which the Boulder Drift furnishes refer it, in every country where it is found, to the

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[1] Sir C. Lyell, *Manual*, p. 144.

Newer Pliocene or Pleistocene period,—that, comparatively speaking, very modern period which all but immediately preceded the present. This latter is called the Post-Pliocene Period, and consists in part of beds thrown down since man was created, which beds contain no remains of any animal or plant which is known to have been extinct before that epoch. The deposits immediately below these are the earlier accumulations of the same period. All the shells they furnish are of species now living, though some of them no longer inhabit precisely the same localities as of old: they are, therefore, said to be locally extinct. Associated with them are bones of a few kinds of mammals, which are no longer in existence; for the continuance of a species among the vertebrate, or highest orders of animal life, is not so long as it is among mollusks. We have descended now to the Pleistocene Period—that of the chief part of the Drift—the very commencement of which must be regarded as, geologically speaking, distant from ours but as yesterday; though when that interval is measured by comparing it with the few thousand years during which man has been upon the earth, a vista is presented to the mind's eye of a length which we are not, perhaps, accustomed to contemplate. However, the fossils of the greater portion of the Drift, whether in our own country, in the North of Europe, or in North America, are of this age, and afford good evidence that the formation was accumulating in those different regions at the same time.[1] Everywhere it occupies a superficial position, which is, of course, in strict agreement with what might have been expected from these imbedded remains, and, like them, points to the contemporaneous late origin of the whole. We are now to give a brief account of it, as it is seen on the continents to the east and west of us.

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[1] Sir C. Lyell, *Manual*, p. 138.

If two persons were to set out from Berlin, the one to make a geological excursion through Denmark and Sweden, while the purpose of the other was to find his way to Archangel with the same object in view, agreeing to meet again at Stockholm, both the one and the other, in the course of their journey, would meet with many fragments of rock scattered on the surface, or mixed up with the soil to a certain depth, which in both cases must needs have been brought from great distances, as no rocks of a like kind, from which they could have been detached, are to be found within hundreds of miles of the countries through which they were passing. In many respects the formation of which these rolled and unrolled stones were evidently an integral part, would have been found by each of them to have presented similar characters. Mud, sand, or clay, sometimes more or less stratified, sometimes in a confused mass, would have been the chief materials of it.

As they travelled northwards, the blocks of stone would meet them in greater numbers, and of larger size, some of them having a circumference of many yards. Upon their comparing the specimens which they had collected from these travelled blocks, it would turn out that, while those which had been furnished by Holstein, Denmark, and Sweden, were of gneiss, syenite, porphyry, and the sorts of trap found in the mountains of Norway, those which had been supplied by Poland and Russia were of the granite which abounds in the mountains of Lapland and Finland. In short, they could come to no other conclusion than that the stony masses had been brought to their present resting places from those several localities, far off in the north-west, on lines pretty much parallel to one another.

To account for so remarkable a phenomenon they might well call to mind the agency of floating ice. They would find that there is abundant evidence in Sweden of the gradual upheaval of the land; and that, at a very recent geological period, parts of it had been covered with water to a depth of several hundred feet. They would be aware that many of the mountains, whence the travelled boulders must have come, have still extensive glaciers, which, in former times, when the land was certainly not so much elevated, and the cold, as they had reason to think, might have been greater, would have reached the sea. They would learn that smoothed, scratched, and grooved surfaces of rock, upon which the floating ice might have been driven, and pinnacles and buttresses with the angles on the "*storm side*" worn away, add their testimony to establish the agency by which the debris had been transported.

That the deposit was, comparatively speaking, very modern, there would be proof before them of the most convincing kind. The extensive country between St. Petersburg and Archangel, for a distance of 600 miles, would have afforded evidence enough of this. There, shells of species all now living in the Arctic Sea, would have been collected in abundance from the strata upon which the Drift, with its enormous blocks of rock, had been since strewn. This portion of it, then, would be at once known by these geologists to be of the Post-

Pliocene Period, or *newer part* of the Boulder formation; and would thus satisfy them that the operation by which these beds were left was long continued, reaching into a second geological age,—that is to say, from the Pleistocene, which, as has been shown, claims the earlier part of the Drift, into the Post-Pliocene, to which these subsequent strata belong; for in Scotland, as they would know, it furnishes shells which are extinct, while here it lies upon beds in which the shells are all recent. Now this fact would be considered by them to be very significant. It would imply, as has been just said, that the Glacial Period was one of no brief duration; for the passing away in any locality of even five per cent. of its mollusks would not be supposed to have occurred in a small space of time.

The testimony of the strata of Sweden, upon this same point, they would discover to be altogether confirmatory of that afforded by the north-west of Russia. Shells of a kind now inhabiting the Baltic would be observed still adhering, in favourable situations, to rocks raised hundreds of feet above the level of the sea; beds filled with recent shells would prove to be common; and over the whole would be seen the Drift with its boulders: everything would bear witness to a Glacial Period with its floating islands of ice.[1]

If our two travellers were now to cross the Northern Atlantic, and were to begin a like exploration of the United States and Canada, from a starting-point even as far south as the 38th parallel,[2] or about in the latitude of Lisbon, as they journeyed northward the appearances presented by the north-west of Europe would be repeated. Lines of boulders from the far north, increasing in size as they were traced to higher latitudes, reposing in the middle and on the surface of similar beds of unstratified mud, the ponderous rocks in close proximity with fragile shells, very few of these being broken or injured, would appear to them to be little like the work of any kind of violent current; but when viewed in conjunction with the smoothing and parallel scoring of rock surfaces, here still more noticeable than elsewhere, would, perhaps, confirm their opinion, that a cold period had prevailed at that time,—the result probably of such a distribution and elevation of the land in northern, and it might be in southern latitudes also, as favoured the formation of ice-bergs and coast ice, which had strewn over this part of the continent, while it was yet submerged, the deposit which is now so remarkable a feature on its surface.

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[1] Sir C. Lyell, *Manual*, p. 126.

[2] Ibid. p. 140.

If the circumstance of the gradual diminution in the size of the transported rocks, as they were found to extend farther from the regions whence they had issued, seemed to present any difficulty in the way of this hypothesis, they might consider that there were many more chances, in every particular instance, that a heavy stone would break away from the ice-raft which bore it than one of less weight. Every time the very frangible[1] mass was rocked by the waves; whenever it might happen to turn over, which, as they would know, is not at all an unusual occurrence; in every instance of its being shattered by contact with other ice-bergs; or when it broke up into pieces from being weathered; upon each of these and other occasions, a block of stone weighing several tons would be far more likely to be dislodged from its brittle setting, they would think, than one of only as many hundredweight.

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[1] Glacier ice is extremely brittle. Professor J. Forbes, in *Geological Observer*, p. 242.

It would suggest itself to them that the larger stones might occasionally set out on their journey upon the smaller rafts; for it would be natural to conjecture that many of the masses of ice which are heard to fall into the sea so frequently from the face of the overhanging glaciers, are torn away by the weight of great imbedded fragments, with which a portion of ice, large enough to float them for a time, but not to bear them to any great distance, might very possibly be detached. They might call to mind, moreover, the difference between an ice-berg from the glacier and ordinary coast ice. The former, they would recollect, would commonly be deep in the water, from its thickness; liable, therefore, to be stranded on any shoal before it had travelled very far; while the latter, loaded perhaps with only smaller stones picked up from the sea-brink, might be driven along for any distance without being so arrested.

It would occur to them, also, while considering the effects of such coast ice, that, as the land slowly emerged, and every part of it in succession became first a shallow and then a shore, upon which fragments of stone had already been dropped, if the cold were still sufficient, as would seem probable, the repeated removal of the stones by these floes would go on long after the transportal of new supplies by ice-bergs had ceased; and that the inevitable consequence would be that the fragments found at the greatest distance from the original centres of dispersion would be the smallest; because, since the frost has great power to split stones, the more frequently fragments soaked with water are exposed to its influence, the more chance there must be that they will be reduced in size. It has been remarked that "in those places where, in the course of centuries, blocks have been carried southwards by coast ice, having been often stranded and again set afloat in the direction of a prevailing current, the blocks will diminish in size the farther they travel from their point of departure, for two reasons: first, because they will be repeatedly exposed to wear and tear by the action of the waves; secondly, because the largest blocks are seldom without divisional planes, or 'joints,' which cause them to split when weathered. Hence, as often as they start on a fresh voyage, becoming buoyant by coast ice which has frozen on to them, one portion of the mass is detached from the rest. A recent examination, in 1852, of several trains of huge erratics in latitude forty-two degrees fifty minutes north, in the United States, in Berkshire, on the western confines of Massachusetts, has convinced me," says Sir C. Lyell, "that this cause has been very influential both in reducing the size of erratics, and in restoring angularity to blocks which would otherwise be rounded in proportion to their distance from their original starting-point."[1] All these reasons might offer themselves to the consideration of our travellers, and convince them that the well-known fact of such erratics diminishing in size as they are traced southward, places no great difficulty in the way of the hypothesis that they reached the spots where they lie by the agency of ice; to which the appearances point rather than to anything like regular sorting by currents of water.

Let us suppose that these two persons now determined to prosecute their researches in the equatorial regions, in order that they might satisfy themselves whether or not these same phenomena are discoverable in those hotter parts of the earth, where the formation of icebergs at any period is scarcely conceivable. In vain would they traverse districts which seem to present every other condition favourable to the production of a boulder deposit, except this one of glacier ice. They might pass over wide-spread lowlands, which, together with lofty mountains that rise from them, had been upheaved from the sea-bottom within the Tertiary Period; which might promise, then, to exhibit the effects of currents of water, set in motion by the tilting of the land when it was upheaved; but no boulder drift would be found.[1] Nothing of a like kind would be seen until they had crossed the Mediterranean on their way home, and had left its shores behind them. But as they approached the Alps, they would again come upon all the characteristics of an ice-borne deposit. Passing round this elevated region, they would find in the neighbouring countries, Italy, France, Switzerland, and Austria, abundance of travelled fragments, evidently supplied by its heights, scattered as usual without reference to the contour of the surface on which they repose. Huge angular masses of rock, hundreds of them as large as cottages,[2] would present themselves, strewn over the plains or perched on the declivities of lofty hills, many of them having been conveyed across the wide and deep valley which separates the Alps from the Jura, a distance of at least fifty miles.

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[1] Sir C. Lyell, *Manual*, p. 130.

They would know, it is true, that none of the glaciers they saw before them in this region descend as low as the sea level, not within three or four thousand feet of it, perhaps; and that it was impossible that they could have been instrumental in the distribution of this drift under present circumstances; but upon ascending to heights within the limits of perpetual frost, which, therefore, could not now produce glaciers, since these depend upon an alternation of frost and thaw, they would there see well-marked glacier valleys, the indisputable evidence of the former existence of these ice-streams amidst those precipices; and again descending, they would find similar traces far below the actual extremities of the present glaciers;[1] while they might discover good reason for thinking that the mountains themselves had formerly stood at a much lower level than they do now, by as much, perhaps, as 2,500 or 3,000 feet;[2] thus making it quite certain that, with a greater degree of cold than that now prevailing throughout the same area—of which they would not find it difficult to collect other evidence—the conditions needful for the production of floating ice would be present, as there are manifest indications that, at that time, water entered far into the recesses of these mountains;[3] and they would probably be ready to coincide at once in the opinion expressed by so high an authority as Sir R. I. Murchison,[4] that "the dispersion of the far-travelled Alpine blocks must have been coeval with the spread of the northern or Scandinavian erratics, which it has been demonstrated was accomplished chiefly by floating ice, at a time when large portions of the Continent and of the British Isles were under the sea;" and that "the great granitic blocks of Mont Blanc were translated to the Jura by ice-floats, when the intermediate country was under water."[1] In short, they would see that, in another region of Europe, perfectly distinct from that surrounding the Baltic, there is good proof that the distribution of a boulder drift is to be ascribed to the agency of ice; and their conviction would be complete, perhaps, that formations of this peculiar character have been thrown down under glacial conditions; since they are never found but in manifest connexion with glaciers, and are constantly accompanied by all the indications of glacial action.

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[1] Sir C. Lyell, *Manual*, p. 139.

[2] Ibid. p. 150.

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[1] Sir C. Lyell, *Manual*, p. 149.

[2] Sir R. I. Murchison, *Quart. Geol. Journ.* No. 21, Feb. 1850.

[3] Ibid. p. 66.

[4] Ibid. p. 69.

They might have discovered reasons for thinking that, in various localities, there are marks of partial and unequal upheaval, and of sudden violence; and that areas have been denuded, and valleys scoured of the deposits which had been previously lodged in them, by the instantaneous upthrow of portions of the sea-bottom, the removal of lake barriers, or by other means of a like kind; and that heaps of rubbish, tumultuously aggregated, have been the result; but they would probably conclude that the general phenomena of the Glacial Period, taken as a whole, are to be ascribed to the ordinary action of glacier and floating ice, doing its work, year after year, and century after century, in that gradual and orderly way—the way of real grandeur, without hurry or perturbation—in which the Great Author of nature is usually seen to bring about His purposes.

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[1] Sir R. I. Murchison, *Quart. Geol. Journ.* No. 21, Feb. 1850, p. 68.

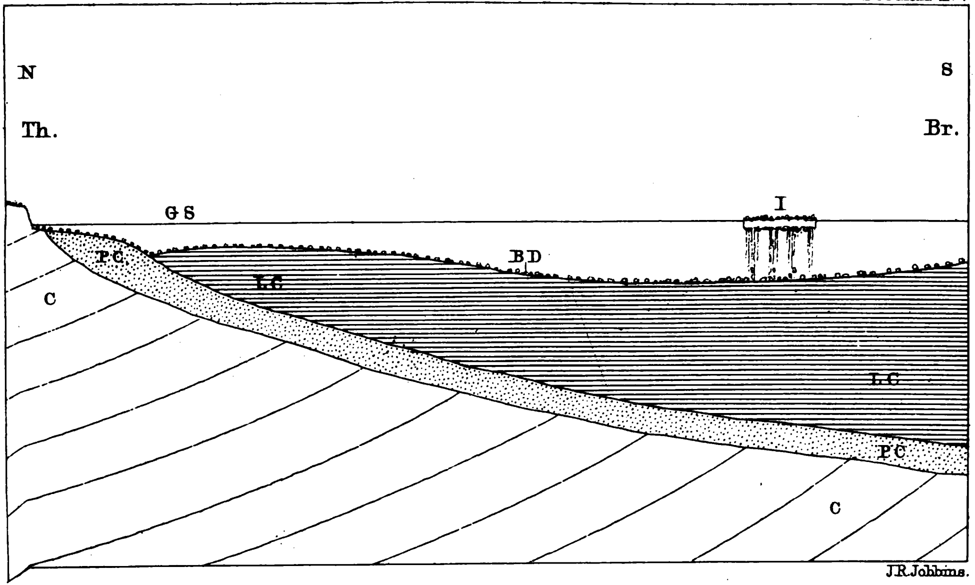
CHAPTER X.

Mineral material of the reader's garden—Relative position of the strata with which we are concerned—Boulders of the Drift from the north—Strata below the Drift from the Chalk upwards—Pebbles in Plastic Clay and in Drift prove oscillations of earth's crust—A hot climate in these latitudes before the Glacial Period—Vast length of time occupied by these changes—Proved by phenomena in France—And in Sicily—Change of temperature possibly caused by changes in distribution and height of land—Fossils in reader's garden may lead to some of these conclusions.

THE accompanying lithograph (Sect. IV.) represents such an incident, connected with the formation of the present surface of the earth, as we suppose might have been witnessed,—could any one have been present,—when the mineral material of what is now, perhaps, the reader's garden was supplied. If he happens to live within the area covered by the Boulder Drift, something like it very probably occurred upon the spot which he calls his home; and this but a short time ago, according to the computation of geology; though how many annual revolutions our planet may have made since the event, it might surprise us, perhaps, to learn. The time during which man has been enacting his important part among created beings would prove to be but a very small portion of it, possibly.

In the figure referred to, is given a section across a part of Essex, from Brentwood, due north, to near Thaxted, which exhibits, nearly enough for our purpose, the present relative position of the strata with which we

Section IV.



J.R.Jobbins.

are more particularly concerned. It will be understood that here is depicted a supposable operation of that period, when the chalk C, to the north of this district, at N, had emerged from the glacial sea, GS, while yet the cold was great enough for ice to form on the coast, and to carry away with it whatever chanced to fall on its surface from the cliffs, or the shingle and finer materials which it might pick up as it froze near the shore. An ice-raft thus freighted, I, is dropping its heterogeneous load, which may be now the mineral matter of any one's garden-soil in that part of our island. There seems little reason to doubt that many a garden could give this history of its origin; and could appeal to its rock-border to convince us that the strange tale was not far from the truth. Thereon might be seen, and examined, a company of unbending, unmistakable witnesses, every one of them ready to testify that, at all events, something like it had happened near that place. Resting on the clay, far enough from the rocks whence they had been originally brought, boulders and fragments of granite, syenite, gneiss, mica-schist, greenstone, basalt, jasper, quartz, limestone of different formations, chalk-flint, and Hertfordshire pudding-stone, all foreign to the locality on which they are now assembled, but collected nevertheless from their sojourning places in the immediate neighbourhood, would give evidence of some mighty agency by which they had been borne over hill and dale, for hundreds of miles in certain instances, to speak to those who would lend an ear to them of the marvellous changes which their parent earth had undergone.

Mineralogists, the competent interpreters of the language in which these witnesses offer their testimony, declare that such an assemblage of rocks must needs have come from the north. Sir C. Lyell[1] cites Dr. Mitchell, as suggesting that the materials of the drift of the east of England may probably have been supplied from lands since submerged or destroyed, which formerly occupied the site of the German Ocean. And he regards the conjecture as by no means unworthy of attention, observing that we are too apt to look only at regions which are still above the water for the origin of such débris as is now to be accounted for, forgetting that it may be the remains of strata which have been entirely removed; and he points to the case of Heligoland as illustrating his meaning. That rocky island, which in times of war has been found so valuable to us for the purposes of trade, is being gradually eaten away by the waves which break upon it; and in the course of time will, in all likelihood, entirely succumb before them. Its lofty cliffs, attaining in some places a height of 200 feet, are of the New Red Sandstone, or Trias, formation; which, notwithstanding its name, is of vastly remote antiquity, as it lies at the bottom of the secondary series; it is called *New* Red, to distinguish it from another sandstone, the *Old* Red, which is of still greater age. It is quite possible, then, that this island might have disappeared long ago, and the boulders and red mud which its destruction had supplied might have been spread over the surface of the adjacent country of Holstein, which was recently, as we have seen, beneath the water. In that case, as Sir C. Lyell tells us, such fragments and rubbish would have been entirely different from the strata on which they rested, having no visible rocks like them—to which, therefore, they could be referred—nearer than those in Hanover, between one and two hundred miles off, in a direction quite contrary to that from which they would have been really derived; and thus most erroneous views about their origin might have been adopted.

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[1] Lond. and Edinb. *Phil. Mag. May,* 1840, p. 376.

There is no doubt, however, from their mineral character, and from the well-marked direction of the Drift in other countries, that the boulders of Norfolk and the contiguous counties, have, for the most part, travelled southward,—some of them, probably, having been brought from Norway and Sweden. But it is by no means impossible, nevertheless, that an occasional freight may have arrived from a different quarter, as a prevailing wind might, of course, propel a sheet of ice towards any point; and such a raft might have been formed and laden in the west as well as elsewhere.

But the diagram given above affords us the opportunity of saying a word or two about the strata below the Boulder Drift, as low down at least as the surface of the Chalk.

The whole of the beds which constitute the earth's crust, beginning with the undermost, are separated, as has been already said, into four principal divisions, comprehending respectively, the Primary, Secondary, Tertiary, and Post-Tertiary Series. As the Chalk is the most recent, and therefore the highest of the secondary series, from its surface upwards, as represented in Section IV., we have the whole thickness of the tertiary group upon that line of section. Had the line been run in another direction, other tertiary beds, here altogether wanting, might have been cut through. It is easy to understand that, while a stratum like the Chalk, being a deposit of an ocean of considerable depth, is very widely spread, other layers may be of more limited area, having been formed in a sea of no great size, or under the influence of local circumstances, at the mouth of a river, or in a shallow bay, perhaps; or, if originally more extensive, great part of them may have been since washed away. Such different deposits may be proved by their included fossils, or by their position in the series, to belong to the same general group; but it will rarely happen that many of them will be cut through in any section of moderate length. In that before us, two only are laid open between the Boulder Drift, BD, and the Chalk, namely, the Plastic Clay, PC, and the London Clay Proper, LC.

Of late many deep wells have been sunk through the tertiary strata, by which it appears that their thickness varies greatly in different places; but it will be sufficient for our present purpose to estimate those with which we are concerned as they are known to occur beneath London, where the Lower Tertiaries, Mottled Clays and Sands, or Plastic Clay, as the same beds are called by different authors, may be from forty to a hundred feet thick; while the London Clay Proper, which rests upon them, has a thickness varying from one hundred to a hundred and fifty feet:[1]—elsewhere they may together attain to double this thickness, or more.

Four or five years ago a well was sunk at Chelmsford into these strata, and at a depth of two hundred and fifty feet was found a bed of pebbles. They were completely rolled chalk flints, so exactly like those which were scattered about the surface, with which every one who saw them was well acquainted, that the bystanders at once pronounced them to be only common black stones. They judged only from their outward appearance; but they were perfectly right. Nothing is to be recognised with greater certainty than flints of that kind, which contain, as those did in abundance, the usual fossils. Of their original location in the Chalk, we may be as sure as we can be of anything in the world. And their occurrence where they were discovered was only what was to be expected, such pebble-beds being a regular feature of the Plastic Clay. The well-digger could have foretold that such stones would, in all probability, be found there.

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[1] Prestwich, *Water-bearing Strata*, p. 24.

But the circumstance, however familiar, is well deserving of consideration nevertheless: it may help to afford very curious information to those who have not studied the subject before. The facts are these;—there are at this place two layers of similar water-worn pebbles, one at the bottom, and one at the top—for our surface-soil, full of these flints as it often is, may be looked upon as a layer of them—with two hundred, or two hundred and fifty feet of mineral matter, chiefly solidified mud, or sand, intervening. Now these two beds of rounded flints, separated by such considerable accumulations as the Plastic and London Clays, make it manifest that this part of the earth's crust has undergone very great changes of level. It is evident from its fossils that the Chalk, whence these flints came, was deposited in a sea of considerable depth. It must, therefore, have been thrust up to the surface, and exposed to the action of the waves, or its flints could not have been ground down to the small rounded pebbles which are found so plentifully in the Plastic Clay. Such beds indicate ancient chalk cliffs, and a shore beneath them, that is, the existence, and the continuance for a long time, of a portion of that deep-sea deposit raised above the waves. But the strata, now resting upon these pebbles, which at Chelmsford are more than two hundred feet thick, were also deposited in the sea; and part of them, as the fossils prove again, in by no means a shallow sea. It is clear, then, that these chalk-flints, after having been exposed to the rolling of the breakers on the shore, which spread them over the surface upon which they now lie, sank down with that surface low enough to receive upon them the whole of the overlying tertiary strata; and after that, in addition, the Drift with its similar chalk-flints. Subsequently, the whole was raised up again to its present level, leaving the upper layer of these water-worn pebbles, in some places, six hundred feet or more above the sea. There were, doubtless, other up and down movements, accompanied with more or less of denudation, the proof of which is not so obvious; but of the great oscillations here pointed out, any one may find evidence.

But the most remarkable fact connected with these strata is this, that, whereas the inquiry in which we have been engaged has brought before us an almost arctic climate as at one time prevailing in these latitudes, the London Clay, which underlies the Glacial or icy Drift, is, in several places, full of fossils which prove that it was supplied by a hot country. It yields a variety of remains—fruits, seeds, shells, teeth, and bones; and they all agree in referring the formation to a period when the climate here was not, perhaps, altogether unlike that of the islands of the Indian Ocean.

These surprising vicissitudes of heat and cold were most probably the result of alterations of surface-level, wrought by the volcanic forces at work beneath. If it can be proved—as is not questioned—that such changes of level have affected strata of a thickness amounting to many miles, and extending over whole continents, it need not be doubted that such a conjunction of circumstances may have prevailed, once and again, in the course of the vast series of ages which have certainly passed since our globe was called into existence, as would produce, in the same latitude, and throughout the same area, climates of the most different character.

It may be thought, perhaps, by those who have not all the facts before them, that the London Clay is so recent a formation, when looked at geologically, that it is not reasonable to suppose the needful change in the height and distribution of the land to have taken place since it was deposited; for it must be concluded that wide-spread torrid regions have sunk beneath the deep sea, and mountain ranges have been upheaved into the realm of everlasting frost, or the results brought about by any cause of this kind could not have been such as we now contemplate. But when we hear of a geological age which is near to our own in comparison with others which are much more remote, we must not be deceived by the sound of the words into a notion that the time which has elapsed since that comparatively modern epoch has not been actually very great. Every fact with which geological science is acquainted tends to show that such a persuasion would be utterly erroneous. The London Clay is apparently of yesterday, when viewed by the side of the Coal Measures[1] which supply our fuel, or the far older Cambrian System,[2] from which we obtain our roofing-slates. But if we call to mind what has happened since the close of that more recent period, and consider that there has been time enough for the extinction of almost all, or even, perhaps, of all, the species of living things then in existence on the globe; that the animal world of that age has passed away, and that all has been produced anew—and this, not by any sudden destruction, and fiat of creation, but by the gradual substitution of species after species as the former kinds died out—we shall not think, perhaps, that the time which has elapsed since the accumulation of the London Clay has been too brief to allow of the changes of level which the vicissitudes of climate, so clearly marked in this region, seem to indicate.

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[1] The group of strata which furnishes the coal is so called.

[2] Several formations connected together by some common character are called *a system*.

In order that we may be able to estimate in some adequate manner the length of time needed for the accumulation of such deposits as those of the London Clay and the beds above it, it would be well to consider the vast changes which can be proved to have taken place elsewhere within the same period,—in such a country as Auvergne, for instance. There, in the centre of France, a most amazing succession of geological events are seen to have occurred, the first of which cannot be of an age earlier than that of the upper, and therefore later portion of the London Clay.

It appears that this interesting region, the foundation of which is granite, lay then in a state of perfect repose. Its moderately elevated mountains were reflected in the waters of several lakes, one of them not less than forty miles long by twenty wide, and hundreds of feet in depth. The same process was going on there as may now be witnessed everywhere else under similar circumstances,—these lakes were being gradually, and we may be sure very slowly, filled up with mud and pebbles, which the mountain torrents carried into them. The Lake of Geneva, which is not very different in size from the one above mentioned, is losing area and depth in the same way; but who shall say what ages must pass before the work is accomplished? The delta of the Rhone, where that river enters the lake, has encroached upon the water to the extent of about a mile and a half in something more than eight hundred years; and of six miles from the point where the accumulation first rose above the surface. This is but small progress towards its obliteration. In the case of the lakes of Auvergne, however, the time required did pass, until they had received, at least, deposits which are in some places several hundred feet thick,—not mere deltas, made up of fragments and coarse matter, but slowly accumulated strata of fine mud. Many of these beds of clay, marl, limestone, and sandstone, frequently containing the remains of numerous species of fresh-water mollusks, and occasionally the bones of mammals, and of other animals—by which, of course, their geological age is attested—are so constituted and disposed as to prove that they were deposited for the most part in tranquil and clear water, and therefore at a very slow rate.

A striking proof of the latter very material fact may be seen in the curious Indusial Limestone of these lacustrine formations. It is very well known that the larvæ, or grubs, of certain flies, which frequent the banks of rivers and pools, live, while they are in that preparatory state, in the water, and protect themselves from their enemies by constructing tubes in which they may lie concealed. The common cad, caddis, or case-worm of the angler, which turns to the stone-fly, is of this sort. Different species of this grub use different materials for their indusia, covers, or cases; some agglutinating together vegetable matter, small sticks, or reeds; others choosing grains of sand; while a third kind prefer the dead shells of small mollusks for the purpose. It is evident that the larger of the ancient lakes of Auvergne was inhabited by a species of the latter family, and that they swarmed in it in a remarkable manner; for their cases, incrusted with calcareous matter, are seen to form there thick layers of limestone,—called *indusial* from this strange origin,—which alternate with the more usual kinds of marl through a thickness of several hundred feet. "More than a hundred of these shells," says Mr. Scrope,[1] "may be counted round a single tube, and ten or twelve tubes may be found packed together irregularly in a single cubic inch of the rock. When it is added that *repeated* strata of this kind, eight or ten feet thick, appear to have covered very many square miles—originally, perhaps, the whole plain of the Limagne, measuring forty miles by twenty—some idea may be formed of the countless myriads of minute animals, belonging to one or two species only of mollusks, which must have formerly lived and died on the bottom or shores of this extensive lake;" and of the length of time, it may be further observed, during which the operation was proceeding.

While the lakes were in the course of being thus filled up, volcanos had burst out around them, and added their cinders, and occasionally lava, to the sedimentary strata, with which these igneous products are seen to be interstratified. The whole region was thus gradually elevated, the remaining waters of the ancient lakes probably drained off, while a prodigious number, some hundreds, of volcanic cones, with their accompanying craters were formed, huge masses of trachyte protruded in a half-fluid state, and vast streams of basalt repeatedly emitted, which spread over the lower grounds, and took possession of the bottom of the narrow valleys. The waters thus dammed up formed new lakes; and these overflowing, became in turn the sources of rivers, which, in the course of ages, cut channels for themselves through the hard volcanic rocks, or the original granite, leaving steep escarpments, or sheer precipices, of one hundred and fifty or two hundred feet high, to tell of the ages which must have passed away while such a process was being completed. And this kind of excavation was reiterated in some places more than once or twice, so that the same district was drained at successive epochs, by streams running at as many different levels; and entombing animal remains, moreover, of several successive creations, Eocene, Miocene, and Pliocene.

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[1] *Central France,* p. 11, Ed. 1858.

Mr. Scrope,[1] whose words we will again quote for the reader's better satisfaction, says, "Let us take, for instance, the two neighbouring basaltic platforms of Gergovia and La Serre, and the bed of basalt which occupies the bottom of the narrow valley that divides them, and which has flowed out of the recent vent marked by the Puy Noir. Here are three long strips of basalt, each of which, by its gradual inclination in the direction of its greatest length, and by the positive remains of the cone of scoriæ in two instances at least out of the three, is proved to have flowed in a state of liquidity from volcanic vents opened upon the high granitic platform, into the basin of the fresh-water formation. Each must necessarily have occupied the lowest levels of that basin to which it had access; and therefore it is evident that, at the period when the lava of Gergovia flowed into its present position, there could have been no lower depression in the immediate vicinity. The hollow, therefore, into which the lava of La Serre flowed, must have been subsequently excavated, as that bed is everywhere,—that is, on every line drawn transversely across both plateaux,—at a lower level by from three hundred to five hundred feet than that of Gergovia which runs parallel to it, and not above three miles distant. Again, by the same reasoning, it is evident that the intervening valley of Chanonat, the bottom of which is now covered by a still more recent bed of basalt, must have been excavated since the production of the lava of La Serre, which overhangs it at a height of more than five hundred feet." Here then are three great and distinctly marked periods in the slow process of excavation; it might be said four, for the rivulet of the valley of Chanonat has subsequently worn away a new channel, from twenty to fifty feet in some places below the substratum of the most recent of the three lava currents.

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[1] *Central France*, p. 203.

These three lava streams, from their different appearance, bear testimony to the difference of their respective ages; the oldest, that of Gergovia, being much decomposed; that of La Serre being considerably more fresh; while the lower current, that of Chanonat, is scarcely less recent in appearance than many of the lavas of Ætna, of which the dates are known. And yet these Auvergne volcanos were quenched before the earliest records of history, no mention being made of them by any ancient writer upon the subjects. The several cones, too, afford like evidence of the long interval which separated one eruption from another; the latest being still entire and undisturbed; the one next in age much worn down, the heavier and more massive of its materials alone remaining; while the most ancient of the three, though still retaining the character of a vent of eruption, is but a mere stump.

Mr. Scrope informs us that examples of this kind might be multiplied endlessly, leading unavoidably to the conclusion that the enormous abstraction of matter which has occurred in this remarkable region was effected, for the most part gradually and progressively, by the excavating forces which are still operating the same results wherever rains, frosts, floods, and atmospherical decomposition have the same materials to deal with,—concluding that "to these agents we must refer the effects in question, of which, *with an unlimited allowance of time*, no one will pronounce them incapable."

That the vast amount of denudation which here forces itself upon the notice of the observer, was chiefly accomplished by the ordinary operations of nature, and certainly by no great waves, or unaccountable bursts of water, is rendered very manifest from the perfectly uninjured condition of many of the volcanic cones, which, being made up of scoriæ and dust, so light and loose that the foot sinks into them ankle-deep, must have been torn up and carried away at once by any such violence. They owe their preservation, as Sir C. Lyell observes, to this very circumstance of their composition; for such is the porousness of their surface that every rain-drop is absorbed as it falls, so that not even a rill can form on their sides, to wear them down in the usual manner. Mr. Scrope thus concludes his observations upon this whole subject:—"The time that must be allowed for the production of effects of this magnitude, by causes evidently so slow in their operation, is indeed immense; but surely it would be absurd to urge this as an argument against the adoption of an explanation so unavoidably forced upon us. The periods which to our narrow apprehension, and compared with our ephemeral existence, appear of incalculable duration, are in all probability but trifles in the calendar of nature. It is geology that, above all other sciences, makes us acquainted with this important, though humiliating fact. Every step we take in its pursuit forces us to make almost unlimited drafts upon antiquity. The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound which to the ear of the student of nature seems continually echoed from every part of her work is—Time! Time! Time!"

We cannot help taking the reader to yet one other region, where events, not less wonderful, though of a much more recent date, will again make evident to him the immensely long periods which geological changes of this kind have certainly occupied.

He will not forget that we are endeavouring to estimate the antiquity of the London Clay. Almost all the animals whose remains are entombed in that formation, are, as we have said, extinct. In the later tertiary beds of Sicily, to which we desire now to introduce him, the case is very different. The more recent of these strata contain scarcely any shells which are not specifically identical with kinds now living in the adjoining Mediterranean Sea: there are hardly more than two or three in a hundred, perhaps, which have passed away; indeed, it has been questioned whether they are not all exclusively recent. We may safely say, then, that these beds are of modern origin, in comparison with those which lie under the Drift of our gardens. And yet how great are the changes which have taken place in Sicily since these strata were accumulated at the bottom of the water! There are mountains two or three thousand feet high, the tops of which are composed of limestone, in which nearly all the shells and corals are of species now in being.[1] Raised high above the sea may be seen such proofs of slow deposition as a bed of oysters, of the common eatable species, twenty feet in thickness, resting upon a solid sheet of lava, which, of course, was spread out at the bottom of the Mediterranean after the underlying strata had accumulated there. In another place a layer of corals, also of a kind still living, shows itself exactly at the same elevation on each side of a valley, which has been manifestly excavated through it since it was upheaved. It is of a species of slow growth, and the stratum is a foot and a half thick, so that, by itself, it represents no very short space of time. The hollowing out of such a valley—and there are many such, of considerable depth—could not be otherwise than a very gradual operation, as it was effected apparently by the ordinary denuding power of rain. The materials of a region, then, which attains an elevation of three thousand feet, were here slowly amassed under the sea; and, it may be, scarcely less slowly raised to their present height. And this has all happened in a very recent portion of the Tertiary Period—the Newer Pliocene, or Pleistocene. But what notion does the word *recent*, so used, convey to our minds? "The more we reflect on the preponderating number of shells of species now living," says Sir C. Lyell,[1] referring to these Sicilian beds, "the more are we surprised at the great thickness, solidity, and height above the sea of the rocky masses in which they are entombed, and the vast amount of geographical change which has taken place since their origin. It must be remembered that, before they began to emerge, the uppermost strata of the whole must have been deposited under water. In order, therefore, to form a just conception of their antiquity, we must first examine singly the innumerable minute parts of which the whole is made up, the successive beds of shells, corals, volcanic ashes, conglomerates, and sheets of lava; and we must afterwards contemplate the time required for the gradual upheaval of the rocks, and the excavation of the valleys. The Historical Period seems scarcely to afford an appreciable unit in this computation; for we find here ancient Greek temples, built of the modern limestone of which we are speaking, and resting on a hill composed of the same; the site having remained to all appearance unaltered since the Greeks first colonized the island." So much for the word *recent* when thus used geologically.

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[1] Sir C. Lyell, *Principles*, vol. i. 310.

Now, this part of Sicily, it will be understood, represents, generally, the same period as the Drift with which we are concerned: the formations, as proved by their contemporary fossils, were, to a certain extent, coeval. If, then, we recall the impression left upon our minds by our brief survey of the changes which have taken place in Auvergne since the middle, perhaps, of the Eocene Period, and remember that these great accumulations at the bottom of the Mediterranean, and the upheaval of them afterwards, occupied but a few of the many ages which those vast changes most certainly required for their completion, we shall hardly think that there has not been time enough, since the deposition of the London Clay, for any oscillations of the earth's crust which can be conceived as possible. With all the facts before us, we shall be inclined to look upon our gardens as though they were ready to move under our feet—more like the waves from which they rose than the terra firma which we have been in the habit of considering them. Of this the reader may be pretty certain, that the part of the earth on which he resides, if it is that of which we are treating, though now producing the flowers and fruits, and inhabited by the animals, of the temperate zone, has experienced within the period mentioned, first, a climate like that of the Philippine Islands perhaps, at all events a very warm one, and then a degree of cold approaching to the rigour of Greenland; and he need not hesitate to believe that such vicissitudes were possibly brought about by changes in the distribution and height of the land—ordinary changes they may be called, as they seem to be always going on somewhere or other, however slowly. A low continent stretching out towards the equator—other parts of the earth being suitably disposed—supplying a great river with a northerly course, emptying itself into the warm sea in which the London Clay was thrown down, might account for that deposit: the rise of lofty and wide-spread lands around the North Pole, extending towards our islands, then considerably submerged, and pouring down a gelid current upon them, after the more ancient southern continent had disappeared, wholly or in part, beneath the waves, would have occasioned the phenomena of the Drift Period perhaps.

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[1] *Manual*, p. 159.

And in all this there is nothing incredible: it may be even said that it is highly probable. The records preserved in the strata beneath us, within easy reach, render the operations of nature in these former ages so manifest that, in their main characters, they cannot be greatly misapprehended. Every flint-pebble we pick up from the Drift, where it rests on the surface of the London Clay, calls upon us to account for its presence in a locality so utterly unlike that in which it was formed. And while we trace its history, the conviction is forced upon us that the deductions of geological science are, so far at all events, unquestionable: evidence of their truth is in our own hands. The solid ground upon which we tread is made up of beds of sediment, which have resulted from a repeated submergence of the land beneath the waves. And since the most considerable of these layers are of clay, or impalpable mud, so fine that it must needs have gathered very slowly—just as the settlement of the ooze in the still pools and bays by the side of a river, out of the reach of its current, goes on by little and little, at a very different rate from the heaping up of the bar of sand at its mouth—we are constrained to believe that these beds, hundreds of feet in thickness, must have required a vast series of ages for their formation—a conviction which is, of course, greatly strengthened when we find that there is indisputable evidence that, during the time of their accumulation, such a diversity of climates prevailed, and such a succession of plants and animals flourished, as the organic remains manifest throughout the area which they occupy. The fossils and water-worn stones which the reader's garden will supply, may lead him step by step to these conclusions, and afford him the means of conjecturing what geology may further reveal to him should he have the opportunity of pursuing it over a wider field of inquiry.

CHAPTER XI.

New lands emerge from sea without a vegetable soil—New island upheaved in 1806—Formation of a vegetable soil—Decomposition of rocks by rain-water—Carbonic acid—Decomposition of granite supplies clay—Decay of vegetation—Vegetable matter not all that is needful—Barrenness of decayed vegetable matter—The Irish bog—Mineral matter required—The earthworm the great vegetable soil-maker—Habits of the earthworm—Its agency in raising mineral matter to the surface—Its operations of geological importance—Not the only soil-maker—Ants effective for the same purposes—Especially in tropical forests—Worms and ants at work at an elevation of 15,500 feet—Their operations may be witnessed in our gardens.

We have not yet, however, examined all the phenomena within easy reach: there is still another wonder of creative wisdom to be considered before we can understand even the geology of our gardens thoroughly.

When the stratum last thrown down, as in Sect. IV., rose from the sea, its surface was, for the most part, merely mineral—clay, or sand, or gravel, as the case might be—without any vegetable matter intermixed; and therefore it was unfit for the support of herbage: it was in that respect much like a newly-laid gravel road, or a heap of clay thrown out of a railroad cutting.

If an agriculturist wishes to make bricks, or dig gravel on his farm, he carefully pares off from the spot selected the upper layer of vegetable mould, which he spreads over the same area again as soon as he has taken from underneath as much of the sub-stratum as he needs for his purpose; and so he loses no ground.

Now, when a new mineral surface is elevated above the waves, the first effort of nature is to produce a similar bed of vegetable soil. For the accomplishment of this purpose a longer or shorter time will be required in proportion as the mineral matter upheaved is or is not easily acted upon by the weather; but it must be done somehow or other before there can be any fertility in the new region which has thus started into existence; and as it seldom can be a very rapid, so it must oftentimes have been a very slow process. In the year 1806, the Fox, or Aleutian Islands, which stretch in a semicircle from Kamtschatka eastward to the American continent, had a new one added to their number. It rose from the sea as a peak, with some low conical hills around it. It was four geographical miles in circumference; and it was inferred, from its size and permanence, that it was not of scoriæ and other light matter, as was Graham Island, which was thrown up in the Mediterranean in 1831, and was soon washed away, but of trachyte—hard rock—thrust up bodily. It is obvious that no very brief space of time would be required before the surface of such a new-born land would be fit for the growth of trees. Lichens would, possibly, soon incrust it; and it would not be long before the meteoric agencies—the alternations of cold and heat, frost and thaw, wet and dry weather—would make some impression upon it. But these inroads upon the stony material would probably be retarded by every additional coating of *dêbris* which gathered on it; for it would thus find more and more protection from the influence of the elements. Still the silent process of decay would go forward, especially upon the more exposed parts; and the time would come when its depressions and level tracts, upon which the loosened matter settled, would be covered with a thin soil, and a corresponding verdure. As seeds arrived, brought by the waves, or winds, or birds, large plants would spring up. Their roots, insinuating themselves into any cracks which might occur, and swelling there, would split off fragments, to be more easily dealt with by the rain-water, which would now begin to be charged with an abundant quantity of carbonic acid, from the decaying matter—the dead leaves of the shrubs and the yearly fall of the other vegetation—by which its solvent power would be greatly increased; and at length the new island would acquire sufficient fertility.

The reader is probably aware that the composition of most rocks is such that the mere rain-water cannot pass over them without tending to their destruction. However small the effect of a single shower may be, the repeated application of even this gentle solvent will make itself felt. If one of the components of the rock acted upon should be iron—which is a common case—the oxygen of the atmosphere, applied to the mineral through the medium of the rain-water, would soon give rise to chemical action—the iron passing to a higher degree of oxidation—and thus the disintegration of the stony mass, however seemingly hard, would be greatly facilitated. If, on the other hand, an alkali, either potash or soda, should be present—which is also very usual in rocks—then any carbonic acid, which the water pouring over them might bring with it, would speedily decompose them. We are in the habit, perhaps, of looking upon granite as one of the most enduring substances in nature; but in reality it readily suffers decomposition from exposure to contact with water containing carbonic acid. Of the three minerals which enter into the composition of common granite, viz., quartz, mica, and felspar, the latter mineral is the most abundant. Now, one of its constituents is potash, which alkali has a stong chemical affinity for carbonic acid. Water charged with that acid, therefore—as, under ordinary circumstances, it usually is—will carry away the alkali from the felspar, and leave clay behind as a residuum. Thus the hardest rock yields a soil which, with a little further change, and the admixture of some vegetable matter, will be well fitted for the growth of plants.

It is very probable that when the spot of ground which is now the reader's garden rose from the sea, it presented little else than a bare face of such clay. But the seeds of the lower orders of vegetables are very generally diffused, and are carried to great distances by high winds and other means; and it would not be very long before such a surface would be covered with a growth not unlike that which we see on our neglected gravel walks; and algæ, lichens, and the humbler mosses, would be the sure harbingers of something better. The decay of this first vegetation would soon make a difference in such a soil, which, of course, would prove to be of a far more tractable character than that of the new island mentioned above. The numerous small cracks produced by the alternate swelling and contracting of the surface, as it happened to be wet or dry, would admit the dead matter, which, blown about in the form of light dust, would, of course, settle in every such small depression; and the rain-water, percolating the mass, would carry it down more deeply. After a certain time plants of a higher grade, the seeds of which are carried about in the crops of birds, and adhering to their feathers, would obtain possession; and the same process would go forward as was just now described, but more readily.

It is natural to think of the decaying vegetation as the chief means of the amelioration of such a soil, and not without reason: the stalks and leaves which fall one year are very needful for the growth of another. But a covering of such matter would not be all that was required to secure fertility. The gardener greatly values leaf-mould, that is, the residuum of decayed leaves; but he knows very well that it is useless by itself. His favourite peat is made up, for the most part, of vegetable matter; but it is, nevertheless, one of the most barren soils he has to deal with: he, perhaps, never uses it without the admixture of sand; and generally incorporates with it also a portion of loam, the chief part of which is clay. An Irish bog is a mass of decaying vegetation; but it is utterly valueless while it is merely such. "Nothing but a covering of earth—clay, marl, limestone, and gravel—will do any good to it. If merely drained, it is as impossible to cultivate as a woolpack."[1] In short, what is wanted is the mixture of mineral ingredients—the clay or other subsoil on which the peat rests.

It is evident, then, that the fall of a great deal of vegetable matter upon the surface would be so far from ensuring a good soil, that, if the mass should ever be as deep, it would be as sterile as a drained bog. To our newly-upheaved region, then—supposing it might be even an island—there would probably be brought, by some means or other, the great vegetable-mould maker, the common earthworm.

[1] Sir D. Neave, *Connemara.*

The worm is very fond of lodging in decayed wood. It will occasionally make its way up the inside of the trunk of a pollard-tree, where decay is going on, and will bring together the ingredients of a vegetable soil in the hollow head above, where grass and other plants will find abundance of nourishment. Such a tree, then, with what may be well called its precious living freight, is brought down by some flood to the sea, is drifted to the newly-raised land, and the earthworm is introduced; and from that moment the fertilization of the surface proceeds with accelerated rapidity.

The common earthworm, or dew-worm (Lumbricus terrestris), although one of the very humblest and most despised, is undoubtedly among the most important creatures in existence. As it is found almost everywhere, few persons are unacquainted with its appearance; although it differs so much in colour and form according to its age, and in size in dependence upon soil and climate, that even those who have written about it have sometimes made several species out of this one. Anglers know it in its different conditions by different names; but their red-worm, brandling, and lob-worm, are all alike the common earthworm. It inhabits holes, which it makes in part by eating its way through the mould, the food it seeks being such decayed organic substances as it finds among or drags down into it. These it takes mixed with a certain portion—seldom, perhaps, less than a fourth, and sometimes much more—of the mineral ingredients of the soil—clay, sand, and grit; and it is surprising to see what large and sharp-edged grains of the latter it will swallow,—whether for the purpose of simply removing them from its excavations, or, like the birds, to help forward the work of the stomach, it is difficult to determine. When it has digested that portion of this strange diet which is digestible, it throws out the remainder, either upon the surface above it, or else into one of its own or of another worm's deserted galleries, in those familiar vermicular lumps which are called worm-casts.

The animal and vegetable portion of the ejecta of worms is no doubt a very valuable manure; but this, perhaps, is not the principal value of their casts; for it must not be forgotten that the chief part of their substance has been previously abstracted from the soil, as the worm feeds upon it; and, however much altered part of it may be by passing through the creature's bowels, it does not seem that the bulk of it acquires any new qualities to add to its worth as food for plants; for, as the worm swallows the small particles of wood and the fibres of dead roots, so, to all appearance, it ejects them, hard and tough. But, as we shall see, these contemned animals have another less obvious, but, perhaps, more important office. Thirty years ago, or more, a letter was sent to the editor of some periodical publication, in which the writer asked an explanation of the following circumstance:—He had manured a grass field with a white substance—bone-ash, or chalk, or lime—and upon removing the turf not very many years afterwards, had found that his white manure had sunk down, in a still visible stratum, to the depth of about three inches, having a dark-coloured loam above it. Several conjectures were ventured upon this remarkable phenomenon, but the right interpretation of it was not then understood; for it can hardly be doubted that it was the work of the worms, which had let down, by means of their excavations, the white matter, which they did not like, and therefore avoided, while they had thrown up their dark-coloured casts above it. The reader may have seen, perhaps, in a little book—"Humble Creatures"[1]—published not long ago, that Mr. Wedgewood, a friend of Mr. C. Darwin's, had observed and comprehended the same process twenty years back. He had seen reason to think that the soil in some of his pasture fields had materially increased in depth within a few years; and, to satisfy himself whether it was so or not, he examined it in several different places, and everywhere found proof of the same singular fact—there was the usual good pasture soil on the surface, and under it the pebbles, cinders, and lime which had been thrown on with the manure. Where this matter had been applied three years before, there he found above it a vegetable soil of an inch in depth; while in another field it was buried three inches deep, itself forming a separate layer an inch thick. Mr. Wedgewood's conjecture that it was the earthworm which had been the agent in this remarkable operation, was fully confirmed by Mr. Darwin's subsequent observations. He found—as is always the case in favourable weather—that well-nigh the whole surface of the grass field was covered with the ejecta of the worm. Although the casts of the larger worms are the more conspicuous, standing up as little mounds at no great distance from one another, yet they may not, perhaps, effect so much upon the whole as the smaller heaps of the greater multitude of younger worms, which are hidden under the herbage. "On carefully examining between the blades of grass," says Mr. Darwin, "I found scarcely a space of two

[1] Page 20.

inches square without a little heap of cylindrical castings."

It is not mentioned in the book quoted that that eminent natural philosopher made any experiments to ascertain the rate at which a worm will occasionally throw up the soil. He probably did so, however, and must have found that the quantity of matter thus moved was sometimes truly astonishing: mould to the amount of two cubic inches has been ejected, under favourable circumstances, in the course of a week. When he says that "the worm is unable to swallow coarse particles," he means, no doubt, small pebbles; for coarse particles it swallows in abundance, as will be obvious to any one who will break up the casts of a large earthworm, or examine the contents of its stomach. It is its faculty of thus bringing up from below a great quantity of mineral matter that appears to render it so important an agent in maintaining the fertility of the earth's surface. The decaying vegetable fibre, being much lighter than the clay, sand, and grit, with which—as in the case of the drained bog, or the pure leaf-mould—it must be mixed before it can form a fertile soil, would naturally maintain its position at the top: there it fell, and there, for the most part, it would lie, until it was dissipated in one way or another, without being of much use for any purpose; but the worms eject their casts upon it, and bury it under a covering in great part mineral; and when the whole is well mingled together by the heavy rains and the tread of animals, it becomes just such a compound—sufficiently adhesive and tenacious, and yet easily permeable—as the gardener likes; and which, under the name of virgin loam, he brings in to his potting-house for his choicest purposes.

As the worms desert their old burrows, the soil sinks in and fills them; and by this means a constant circulation is continued, the vegetable mould extending itself downwards, while the "dead soil"—that is, the purely mineral matter—is brought up, and so the cultivable staple increases. If we examine even the unmoved gravel in the pit, wherever it is not too deep below the surface, we shall find that the worms are invading it, eating out the sand between the stones, and running their excavations down in favourable places, plastering them, too, round the sides, with the peculiar slime and earthy matter with which they puddle them to keep out the wet, and leaving their excrement in them; thus gradually changing the colour of the mass, and making it fit for the roots of the herbage above to strike into.

It is believed to be a mistake, however, to suppose that the growing vegetation is supported chiefly by vegetable decay. A certain essential portion of its carbon—that is, its vegetable matter—the rising plant, it is thought, must thus obtain; but it is dependent upon the atmosphere for its chief supply, having the power of elaborating carbon from it by means of its leaves. What the plant specially wants from the soil is mineral matter; and this the earthworm keeps within its reach, by continually transferring it from below upwards, in a properly comminuted state. Every shower that falls washes away some of this valuable matter, as any one may see who will watch the rills which trickle over the surface at the time; and if the rain is heavy, it carries off a great quantity of clay and sand. The unavoidable consequence of this natural operation would be that the upper layer would consist chiefly of the coarser materials, the larger grit and stones, which would be ill adapted for the support of the more valuable kind of herbage. But the earthworm supplies the waste; and in this way is an agent of which geology must take notice; for denudation and its consequences—the filling up of valleys and lakes, the growth of deltas at the mouth of rivers, and the accumulation of strata on the sea-bottom—would all go on more slowly if the worm did not bring up fine matter to the surface for the rain to sweep off.

The earthworms are not, however, the only mould-makers. In the ants they have active, and in many places efficient, coadjutors in that work. These wonderful insects, as is generally known, live in communities, like the bee, a great multitude of them being associated under a sort of government, occupying a common nest, and, according to their several offices, taking part in all the labour which is needful for the general good.

It is with their habitations, however, that we are concerned; and it will be seen that these very generally answer the same important part in the economy of nature as the worm-casts: they keep a supply of mineral matter on the surface, where the soil would be otherwise covered up and rendered unproductive by masses of half-decayed vegetable fibre. Dr. Livingstone observed this beneficial result of the labours of the ant in the tropical forests of Africa.[1] "These insects," he says, "are the chief agents employed in forming a fertile soil. But for their labours, the tropical forests, bad as they are now with fallen trees, would be a thousand times worse. They would be impassable on account of the heaps of dead vegetation lying on the surface, and emitting worse effluvia than the comparatively small unburied collections do now." And again, speaking of the more open country.[1] On these flats "are many mounds where the gigantic ant-hills of the termites have been situated. No one who has not seen their structures can fancy the industry of these little labourers. They seem to impart fertility to the soil which has once passed through their mouths." No doubt this communication of additional fertility to the spots on which the termites have worked, when compared with others which have not had the same advantage, depends upon their habit of heaping up mineral matter to raise and strengthen their citadels, which is thus incorporated with the decaying vegetable fibre.

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[1] *Missionary Travels*, p. 540.

That our ordinary ant-hills are constructed of the mineral portion of the soil on which they rest, any one will be convinced who will examine them in our pastures; and this seems to be the material chosen here by the whole genus with but few exceptions. "The structure of the turf-ant, a small species, consists of small grains of earth, piled up without any other cement than water. We have seen it made up almost wholly of grains of sand." "The yellow ant uses the dust of decayed wood, and mixes this with earth and spiders' webs." "The nest of the fallow ant, the largest of our British species, presents a rude appearance. Externally it seems nothing more than a hillock of sand and earth, with bits of wood, dried particles of leaves, portions of twigs, and even grains of corn, all mingled together." "The brown ant makes storied habitations of clay." "Many ants in the warmer parts of the globe make wonderful structures, which have attracted the notice of travellers. Malouet saw, in Guiana, ant-hills from fifteen to twenty feet in height, and from thirty to forty feet in circumference at the base." "Others, again, make huge nests of clay in the trees, conspicuous at a great distance."[1] In other instances these insects prefer underground dwellings, and then they throw out on the surface the clay and sand which they remove from their excavations.

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[1] *Missionary Travels,* p. 203.

It is manifest, therefore, that wheresoever these little creatures swarm, as they do frequently in the uncultivated regions of the world, their labours, like those of the worms, must have a very notable effect upon the constitution of the soil; and that, precisely in the places where there would be the greatest deficiency of mineral matter on the surface—that is, in the warm and damp inter-tropical forests—there their efforts are the most energetic and the most effective. And it is further well worthy of remark that both ants and worms pursue their important vocation to the very limits of vegetation: wherever they can be of use, there they seem to be present. Not only on the lower parts of the Himalaya did Dr. Hooker find "the soil and bushes everywhere swarming with large and troublesome ants," accompanied with "enormous earthworms," but when he had reached a height of 15,500 feet, they were still to be seen "on the sunny exposures."[2] We may well suppose, then, that wherever a surface of rock has crumbled down into such a layer as will give a footing for the establishment of a plant, there these joint pioneers of cultivation are ready to begin their operations.

We may witness something of all this even in our own gardens; where may be learned, too, its ultimate purport. A newly-laid gravel walk, as has been already said, is a tolerably exact representation of many a hill-top when it first emerged from the waters in which its materials had been deposited. And if man is not careful in keeping such a walk in order for his own use, it is curious and most interesting to observe how soon the little creatures, whose mission it is to make it productive for the general benefit of living things, begin their work upon it. Should it chance to be in a damp situation, the worm invades it from each side, breaking into it from underneath, lifting up small patches of it, and ejecting upon the lichens and mosses, which it is sure to produce, its valuable casts, drawing down into it, too, whatever dead matter, animal or vegetable, may lie on the surface within reach. If, on the contrary, it should be well drained, then the ant takes possession, either covering it with its collection of mixed mineral and vegetable particles, or driving its galleries through it, into which the same elements of fertility are afterwards to be conveyed. In the meantime the whole is more or less overspread with a growth of sand-worts, or other plants which delight in such an arid surface, to supply decaying matter and further the process. In short, as of old it was thought that nature abhors a vacuum, so may we conclude from what we see going on everywhere around us, and even on a garden-path, that she certainly dislikes unproductiveness.

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[1] *Museum of Animated Nat.* vol. ii. p. 379.

[2] *Himalaya,* vol. ii. p. 93.

When the reader next looks upon his garden, then, it may give an additional interest to it if he recollect that its mineral matter was possibly thrown down from an ice-berg floating over a deep sea above, and the vegetable soil chiefly prepared for him by the worm; for, to close this chapter with the words of Mr. C. Darwin, "although the notion may appear at first startling, it will be difficult to deny the probability that every particle of earth forming the bed from which the turf in old pasture-land springs, has passed through the intestines of worms."[1]

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[1] *Humble Creatures*, p. 23.

CHAPTER XII.

Recapitulation—Conclusions apart from uncertain speculations—Changes which geology reveals part of a foreordained plan—Prepared the earth's surface for the occupancy of man—Such provisions call for gratitude—Geology makes known to us beneficent designs of Providence—Furnishes arguments in support of natural religion—May correct misapprehension of passages of Scripture—Conclusion.

In the preceding chapters an endeavour has been made to give a plain account of some elementary matters bearing upon the geology of that spot of ground which the reader, perhaps, cultivates. Much of what has been said is unquestionably true of it, if it happens to be situated in that half of England with which we have been chiefly occupied; and we cannot help hoping that the other part of the discussion, which, of necessity, has gone more or less upon hypothesis, will not have been wholly unsatisfactory to him. We will now briefly recapitulate, in proper order, the chief conclusions to which the facts examined must necessarily lead us, apart from any uncertain speculations upon them. It will be understood that there are a great many other phenomena connected with the portions of the earth's crust which we have been considering, and that they lay open the history of these strata much more completely than do those to which our limited space has confined us. This further advance in geological knowledge, the reader may, perhaps, be able to make with other assistance. The task we undertook was that of supplying him with a guide to some simple truths, based upon evidence which he would find it easy to obtain at little cost, with the object of enabling him to judge for himself whether he may rely upon the enunciations of geological science in general or not.

This evidence and these conclusions, then, may be viewed in the following natural sequence. The Chalk consists almost wholly of the harder parts, either entire or fragmentary, of marine animals. It must, therefore, have been deposited in layers, generally speaking horizontal, at the bottom of the sea. Among these layers are courses of flints, containing in unnumbered multitudes, the same fossils as abound in the chalk. Resting upon the Chalk of this part of England is a set of strata called the Lower Tertiaries, made up, in some measure, of beds of these flints, so perfectly rolled into pebbles that the operation can be referred to nothing else than waves breaking for ages upon a sea-shore, and washing away cliffs of chalk, from whence alone such flints could have been derived. Some part of the Chalk-sea bottom, therefore, was already tilted and upheaved above the sea-level at the time these pebbles were rounded; for otherwise there could have been no cliffs yielding such flints to be so dealt with.

These pebbles, washed out of a portion of the Chalk which had emerged from the water, and strewn above another portion of it which was still submerged—much such a process as any one may see going on between Brighton and Rottingdean at the time of high tide upon many a stormy day—sank subsequently to greater depths; for upon the top of them rests, not only much of the Plastic Clay which contains them, but the whole thickness of the London Clay, which is proved, by the fineness of its texture, to be the deposit of a still, and therefore deep sea. From these depths the whole of these strata, together with the Chalk on which they rest, were again upheaved. It is not meant that they were finally raised in their present state immediately after the London Clay was accumulated. It is certainly known that great changes took place in the interval; and it is well established that a vast length of time must have elapsed between the one operation and the other. But the consideration of these intermediate movements, and of the beds belonging to more than one geological period, that resulted from them, we were compelled to pass over, as the discussion of so much additional matter could not have been brought within our limits. Upraised at last, however, the forementioned strata certainly were, for they are at this moment open to our inspection, over a wide area, in the hills and valleys around us. During their last great depression they received from the waters their covering of Drift, a strange medley of clays, sands, and gravel, containing, as any one may easily find, masses of pudding-stone, sometimes of large size, rolled and unrolled, from the Plastic Clay, flints, worn and unworn, from the Chalk, with a great deal of chalk itself in small rounded pieces, besides a multitude of boulders and angular fragments from the still older formations which come to the surface more to the north: all this it is believed is incontrovertible.

The surface on which the reader is supposed to dwell was, in this condition, thrust up from the sea; and it must have risen bare and desolate, as the sand-bank, or patch of clay, which he may have seen at low tide at the mouth of a river. It has since acquired its upper fertile stratum, which has been the result of agencies, animate and inanimate, still in operation. Every growing plant has abstracted from the atmosphere a portion of carbon, which, in the form of woody fibre, it has left in the soil as decaying roots, or dropped upon the surface as withered leaves and stalks, or as branches and trunks of trees. The worm, with assistance where required from the ant, and helped, too, by other animals, has buried this vegetable matter, heaping up over it, or mingling with it, a due proportion of mineral ingredients, to form that mould which has been absolutely essential for the support of the vegetation upon which has depended, here as elsewhere, the existence of all things living upon the dry land. This is the astonishing history of the ground upon which we tread.

"Known unto God are all his works from the beginning."[1] The significance of this great truth strikes with new force, when the facts which geology contemplates come into view. The revelations of this science enable us to look back upon the visible creation through a course of ages, the commencement of which is so distant that at first we venture on timidly when we endeavour to reach it in idea. And yet who can doubt for a moment that all the various changes which the strata make known to us were part of a perfectly foreseen plan, to be worked out under the operation of preordained laws, which could not fail to produce the intended result? It was the divine purpose to introduce upon this scene a rational creature—man. This creation of the human species at a certain moment was not more surely willed than was the lengthened process of making the earth fit for the intended occupant. Man

[1] Acts xv. 18.

alone, of all its inhabitants, could arrive at the knowledge of such providential care. None of the lower orders of creation would be sensible of a want of suitable accommodation, or could feel grateful that its needs had been foreseen and adequately provided for. But man can hardly fail to perceive his own requirements, and, from the manner in which they are supplied, can estimate the motive which actuates Him from whom the supply proceeds. He, therefore, can render a due return of gratitude for it; and everything he sees around him teaches him to fulfil that duty.

Geological science brings before us many a fact which exhibits, in a clear light, the care with which Providence has furnished the earth for our convenience. What is more conducive to the comfort of man than mineral coal? So remote, however, was the age in which that deposit was accumulated, that it might have lain miles deep below the other strata; but instead of this, a plentiful supply of it is, in many places, so near the surface, as to be easily accessible to him. In how many ways does iron serve him? The abundance of that metal within his reach corresponds with its great worth. Gold — a most useful substance as a representative of value or circulating medium—has not only been brought to the surface, but being, in its natural position, imprisoned in the hard and intractable quartz, with which the skilful miner scarcely knows how to deal, it was set free from it by the operation of natural causes in recent geological times, so that man, before he had made any great advance in mechanical contrivances, was able to avail himself of it, as he had little else to do but separate it from the sand which had been washed down with it from the mountain tops. Copper and lead, both metals of great utility, are also abundant, and to be had in return for a moderate amount of labour.

If we look at any geological map, we may observe that the greater part of what is now dry land was beneath the waters of the ocean up to a late period: man lives generally upon what was not long ago the floor of the sea. It is well worthy of remark, then, that so many of its constituents, brought up within view, should be so well adapted for his use. Building-stone of various kinds, brick-earth, slate, gravel, and that most valuable material, limestone, which is found in such great abundance, and is so widely spread, all bear witness to the providential care bestowed upon the furnishing of the earth as a fitting residence for the human species.

Geology seems also to lay open to us the interesting, and, as regards its bearing upon natural religion, the very important fact that, in both the vegetable and animal kingdom, there were changes made, not long before the introduction of man upon the earth, as though on purpose to render it more convenient and more agreeable to him. It appears that among the plants of the older formations, so far as is known, there were none of those which are now found useful for cultivation.[1] The period during which the ancient coal-beds were formed was specially abundant in vegetable productions; and the plants that then flourished supplied that store of mineral fuel which is now so essential to man's comfort and progress. But among these has been detected not one of those kinds which furnish him with food. If from that remote period we trace the successive floras, or groups of plants which flourished together at any one time, nearly to the top of the Secondary formations, they do not appear to have been such as would have suited man, as he is a gardener, a tiller of the earth, or a herdsman. There is evidence that, at the time when the upper beds of the Chalk series were deposited, a change in the vegetation of the earth was introduced, which brought it somewhat nearer to that which obtains at present; but it was during the Tertiary ages that the needful transition was chiefly accomplished; and there are even entire families of plants, which man could ill spare, that have left no traces of their existence until quite late in that period. "Some degree of doubt," says Mr. H. Miller,[1] "must always attach to merely negative evidence; but Agassiz, a geologist whose statements must be received with respect by every student of the science, finds reason to conclude that the order of the Rosaceæ—an order more important to the gardener than any other, and to which the apple, the pear, the quince, the cherry, the plum, the peach, the apricot, the nectarine, the almond, the raspberry, the strawberry, and the various bramble-berries belong, together with all the roses and potentillas—was introduced only a short time previous to the appearance of man. And the true grasses—a still more important order, which, as the corn-bearing plants of the agriculturist, feed at least two-thirds of the human species, and, in their humbler varieties in our pastures, form the staple food of the grazing animals—scarce appear in the fossil state at all: they are peculiarly plants of the human period."

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[1] Miller's *Testimony of the Rocks*, p. 47.

Together with the grasses, its proper food, came an animal inferior to none in its value to man. The sheep most probably preceded our race by a very short time, as no fossil remains of it are found in any of the strata.[1] When we reflect upon the manner in which that gentle animal ministers to two of our most urgent needs—the millions of the human race that it clothes as well as helps to feed; and consider how completely its habits fit it for domestication, how readily it is propagated and improved under our management, and how much it owes to us for our care and protection, thus affording us the great satisfaction of knowing—as in the case of other domestic animals—that its alliance with man brings with it advantages which quite compensate for what it has to give up in exchange for them, we can scarcely be wrong in concluding that it was specially introduced for our benefit: no gift can be imagined more useful than this, and it came at precisely the right time.

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[1] *Testimony of the Rocks*, p. 48.

And the same may be said of one of the chief of the genera of fishes. The codfish, and those immediately related to it, if they do not supply our tables with the greatest delicacies, yet, even in that respect, take no very low rank; and, as affording a vast quantity of wholesome and palatable food, so easily procurable as to be extensively used among the masses of mankind, must be regarded as second in worth to no others.[2] Fish of the salmon and the turbot kind, Mr. Miller tells us, "were ushered into being as early as the time of the Chalk; but the gadidæ, or cod family—that family to which the cod proper, the haddock, the whiting, the coal-fish, the pollock, the hake, the dorse, and the ling belong, with many other useful species—did not precede man by any period of time appreciable by the geologist:

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[1] Miller's *Testimony of the Rocks*, p. 104.

[2] Ibid. p. 68.

no trace of the family has yet been detected in even the Tertiary rocks."

While, therefore, the study of geology displays to us, by evidence preserved from the remotest ages, the general truth of the words of the Psalmist, "Thou openest thine hand, and satisfiest the desire of every living thing,"[1] it also shows us the special care with which provision has been made for our needs. It might be added, that it tells us in no very doubtful language, that much more than our mere necessities have been considered. Flowers, gay-coloured and sweet-scented, and the brightly-painted lepidopterous insects—the moths and butterflies—which sip their sweets, and the bee which gathers those sweets, and treasures them up so that they are accessible to us, and the "spinning worm," which furnishes the material for that most beautiful of all woven fabrics, silk,[2] all this pleasing

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[1] Psalm cxlv. 16.

[2] "Doubtless the most valuable product of insects is silk. To estimate properly the importance of this article, it is not sufficient to view it as an appendage of luxury unrivalled for richness, lustre, and beauty, and without which courts would lose half their splendour; we must consider it as what it is, the staple article of cultivation in many large provinces in the south of Europe, amongst the inhabitants of which the prospect of a deficient crop causes as great alarm as a scanty harvest of grain with us; and, after giving employment to tens of thousands in its first production and transportation, as furnishing subsistence to hundreds of thousands more in its final manufacture, and thus becoming one of the most important wheels that give circulation to national wealth.

"But we must not confine our view to Europe. When silk was so scarce in this country that James I., while King of Scotland, was forced to beg of the Earl of Mar the loan of a pair of silk-stockings to appear in before the English Ambassador, enforcing his request with the cogent appeal, 'For ye would not, sure, that your King should appear as a scrub before strangers;' nay, long before this period, even prior to the time part of creation appears to have been reserved—in its fullest development at least—for that period of the earth's agè in which man was to take his place;[1] and grateful thanks, and willing and loving service does he owe to the Great Creator for such benefits.

As these observations have been made upon the truths which geology—that "book of nature"—teaches in connexion with the subject of religion, it may be expected, perhaps, that something should be added in relation to their bearing upon the interpretation of certain portions of that other Divine Record, in which we are so much more deeply interested than we are in any scientific inquiries.

It seems plain, then, that it must have been designed that those passages of Scripture which refer to natural phenomena should receive such an interpretation at any time as man's knowledge at that time should warrant him in putting upon them; and that, as his attainments in science should enable him to correct his former misapprehensions, he should feel himself not only justified in immediately seeking a new exposition of those passages, but obliged to do so, by a regard for truth. Now, as respects two great events recorded in Scripture

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that silk was valued at its weight in gold at Rome, and the Emperor Aurelian refused his Empress a robe of silk because of its dearness, the Chinese peasantry in some of the provinces, millions in number, were clothed with this material; and for some thousand years to the present time, it has been both there and in India—where a class whose occupation was to attend silk-worms appears to have existed from time immemorial, being mentioned in the oldest Sanscrit books—one of the chief objects of cultivation and manufacture. Silk, therefore, is a gift to man, 'scarcely inferior to that of wool.'"—Kirby and Spence's *Introduction*, 1858, p. 188.

[1] *Testimony of the Rocks*, p. 54.

—the creation of the world, and the flood—it is obvious that there may be thus much in common between them and natural phenomena; there may be still in existence such traces of the course and progress of the one, and still discoverable such indications of the limits of the other, as shall give to those advanced in science a more exact view of them than any one can obtain from the study of Scripture only. And, if so, they stand thus far on the same ground with natural phenomena; and it is unavoidable that we should form our opinions about them, and understand those passages of Scripture which relate to them, accordingly.

But the time does not appear to have come when an attempt to determine the meaning of these places of Scripture by the help of science could be satisfactory. We must be content to look upon ourselves as in a state of transition, from old opinions which cannot be maintained, to some new views for the establishment of which we have not all the requisite data. Can it be fairly objected to commentators as a fault, then, that they have continued to explain these passages in the literal sense, in conformity with what they themselves, and most others, thought the general current of tradition and natural appearances, and so with truth, until advancing knowledge has convinced them that they are wrong? From all the old sources of information we learn the great fact—which geology fully confirms—that man was created only a few thousand years ago. What wonder is there that it should have been generally supposed—the words of Scripture admitting such a view—that the rest of the visible creation had its beginning at the same time? Geological science has now taught us that the lower creatures preceded man upon the earth—some of them by myriads of ages, perhaps; but it cannot be said as yet to have given us all the particulars of their history; and until it shall have done so with at least some approach to exactness, it ought not to be demanded of students of the Bible that they should at once come to settled opinions upon such matters. We should not forget that revelation also tells us that all this multitude of beings had their beginning before man. May we not, for the present, rest satisfied with so much of agreement as this?

With reference to religion, however, one of the most important facts declared in the history of creation is that of the descent of the whole human race from one pair. Now upon this material point science speaks as decidedly as Holy Writ. No one can say that, looking upon the strange varieties of colour, form, feature, usages, and language, which are found among the human family, it is more natural or more easy to believe that the whole of it had a common origin only about six thousand years ago, than that men sprang from several different stocks. We know, certainly, that the tendency among all nations has been to claim for themselves a descent more honourable than that of those around them, and so to refer different peoples to different origins. When, therefore, the sacred records are found to maintain the contrary view, and to make it the foundation of the religious system they teach, and science goes completely with Scripture as to the matter of fact, against the common opinions of mankind, we may well be patient if, upon other points, these two authorities should occasionally seem to be divided: we may rest satisfied that the difficulty will pass away in time, as others of a like kind have done before.

But, in the meanwhile, all such difficulties show how needful it is that our religious belief should have a solid foundation; that we should make ourselves masters of the evidences of revealed religion. Those who have duly weighed all that may be said for the Christian faith, never have been, and never will be, much troubled about such questions as geology has raised. If any one is so strangely and culpably indifferent to his own interests, as well as to his duty, as to neglect the examination of the evidences of Christianity, in which he is deeply concerned, while he takes infinite pains, perhaps, to satisfy his curiosity upon some scientific question in which he has no personal concern whatever, he will have himself only to blame if the difficulties of the Scriptures—which are scarcely of any moment at all as respects the question of their substantial truth—should assume in his eyes so exaggerated an importance as to leave him without religious convictions of any value.

Under such unhappy circumstances he may easily persuade himself that he cannot be obliged to run counter to what he considers to be his natural inclinations, and to follow a course for which at present he feels no liking, upon any inducement which has so little certainty in it. But it would be well for him to remember that man's condition here is such as to require him to act perpetually, in all that is most essential to his safety and happiness, upon the best evidence he can obtain, although it may not be always quite satisfactory to him: perhaps there will scarcely be an important step which it will be necessary for him to take, from one end of his life to the other, in which he will feel certain that he sees his way clearly before him.

He may fret under such a condition if he is pleased to do so; but he cannot alter it. And a fair consideration of the whole matter would convince him that it is very philosophical to conclude that it is just that one which will at last prove to have been the fittest for him; that the end of his being would not have been answered if he could have attained to certainty in such matters; that, in a word, since there have always been difficulties in the way of man's faith, and most probably, from one cause or another, always will be, they should be regarded as an essential part of his moral training and probation, one from which he could not have been exempt, and yet have recovered and maintained that rank in the series of reasonable beings which it was the Creator's will that he should occupy.

And now, for the satisfaction of those who are inclined to think that all such "meditations" as have been here pursued would be better let alone, as being, upon the whole, of a dangerous tendency, we will finish with the words of Bacon:—"If the matter be truly considered, Natural Philosophy is, after the Word of God, at once the surest medicine against superstition, and the most approved nourishment for faith; and therefore she is given to Religion as her most faithful handmaid, since the one displays the Will of God, the other His Power. For He did not err who said, 'Ye err in that ye know not the Scriptures and the power of God;' thus coupling and blending in an indissoluble bond, information concerning His Will, and meditation concerning His Power."

APPENDIX.

Shell Prisms—Sponge Spicules—Foraminifera, or Polythalamia—Fish Scale—Spiniferite—Ventriculites—Echinites, and their Spines—Branching Sponge—Pentacrinite—Hertfordshire Pudding-stone—Rolled Flint—Unrolled Flint from gravel-pit.

As the descriptive matter required to make the reader acquainted with the various organisms which will offer themselves to his notice while examining the flint pebbles would have caused an inconvenient break in the thread of the argument, if it had been introduced in the foregoing pages, it was thought advisable to throw everything of that kind into an Appendix, in which the Plates should be explained, and so much given of the natural history of the several animals represented by the fossil remains, as seemed needful for their better elucidation.

Plate I., Fig. 1,[1] *a* to *d*.—SHELL PRISMS.—The fossil form which of all others is the most abundant in the flints from the chalk is the shell prism. There are few such pebbles, perhaps, in which these remains could not be found. When in their simplest condition they are peg-like bodies, having most commonly one blunt and one pointed extremity; but not unfrequently they are sharp at both ends, as at Fig. *d*. Although when floating in the flint they usually appear to be round, they are in reality prisms, with three or more flat sides, as they are here represented. Before they are separated by the progress of decay they are joined side by side, as at Fig. *a*, like the cells in a honey-comb, though not often with so much regularity.

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[1] The sign x means "magnified;" x 10, means magnified ten times; x 20 and x 100, magnified 20 and 100 times, and so on.

These fossils require but little explanation. It is proved, by the remains which are to be found everywhere in the chalk, that, in the sea which deposited it, there was an abundance of certain bivalve mollusks,[1] with shells of a peculiar structure. They were not formed of the same kind of horizontal laminæ, or plates, as are seen in the shell of the oyster; but of prisms—many-sided slender columns—which passed vertically through the shell, from its inner to its outer surface. One consequence of this conformation was a great degree of brittleness: the dead shells soon broke to pieces, and, as their decay proceeded, separated into the prisms of which they were originally constituted. Fragments of the *Inoceramus Lamarckii*, a large bivalve of this kind, are to be found affixed to the outside, or enveloped in the substance of many flints; and the prisms, either single, or two or three united, are almost everywhere met with in the greatest profusion, as well in the chalk as floating in the flint: they will soon become very familiar objects to those who are engaged in these investigations. They, of course, differ greatly in size, according as they come from larger or smaller shells, or from the thicker or thinner parts of them.

The small pieces of such shells, which were originally inclosed in the flint, having been very commonly dissolved, have left cavities in the stone with the top and bottom parallel to one another, and columnar sides—a sort of miniature likeness of Fingal's Cave—with, not unfrequently, siliceous stalactites reaching from the roof to the floor. One of these impressions upon a chip of flint, with the upper part ground away for the better exhibition of the bottom and sides, is represented of the natural size at *b*, Fig. 2, Pl. I.

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[1] Shell-fish, having two shells united by a hinge, like the common mussel: univalve shells are those which have one shell only, of a spiral form, as in the snail.

Plate I., Fig. 2, *e* to *t*.—SPONGE SPICULES.—Some kinds of sponge spicules are also very common, especially those with the letters *g*, *h*, *k*, and *p;* though few of the others will long escape a careful search. When immersed in the flint, they are generally of the same milky colour as most of the other fossils; but they are to be detected occasionally adhering to, or partially lining certain tubular channels, which, in a branching form, run from end to end of some flints, such being themselves fossil sponges.

Connected with these spines, and occurring, though more rarely, in the substance of the flints, and in the same tubular passages, are very beautiful patches of network—at *m*, Fig. 2, Pl. I., a small portion of one form of this network is given. The simple solid globule, as at *k*, though usually without the shaft attached, is everywhere disseminated. The globule with spines (*i*) is just as rare.

The true nature of the sponge remains still an unsettled point. The boundary which separates the animal from the vegetable kingdom, so far as the knowledge of the naturalist extends at present, is of so indefinite a character that, in particular instances, great difficulties stand in the way of determining to which of those divisions certain organizations belong. There is a large group of minute microscopic objects, the Diotomaceæ, which until lately were regarded by most persons as animalcules; and to an ordinary observer, who saw one of them moving about in the water, to all appearance with a determinate object, and then, perhaps, rolling an atom of sediment up and down its whole length, first on one of its sides, and then on the other, there would seem to be no doubt of it. But they are now claimed by the botanist as in his province, and are most commonly held to be vegetables. The sponge, on the contrary, fixed to the rocky bottom like a sea-weed, would be thought by those not skilled in such inquiries to be some kind of plant; and many a fungus which grows attached to trees, or in the woods, might supply him with what he would readily think a tolerably good object of comparison. But it is generally considered, nevertheless, that sponges should be assigned to the animal kingdom. Some writers, indeed, look upon them as a sort of link by which the two kingdoms are united; and so regard them as holding an intermediate place, and partaking of a double character—as, literally, animal plants.

The reader is, perhaps, aware that what are called Zoophytes, that is, animal plants, such as corals, and the organisms allied to them, are truly animals, although they have oftentimes a very plant-like form. They are attached to the sea-bottom by what looks like a root, and throw out, as they grow, what may be compared to branches; but they have no real connexion with vegetables notwithstanding—their nature is animal throughout.

It would be quite out of place here to enter into any discussion of the difficulties which stand in the way of determining the real character of sponges: all that can be done is to give a description of them so far as is necessary to explain the nature of their remains which are found fossil in the flints.

Most persons are sufficiently well acquainted with the appearance of the common sponge as it is imported from the Mediterranean for domestic use: uncut specimens of more than one kind may be seen displayed at all times in the windows of those who sell them. But it may not be known to everybody that the cup-shaped, or globular tissue of interwoven fibres which he purchases, is merely the framework of the animal: it is no more the sponge itself, than the skeleton is the man. When alive this network was covered everywhere with a gelatinous coating, much as though it were now dipped into white of egg, or something a little more tenacious with which had been mingled a multitude of transparent granules. This glairy matter had the power of secreting the tough elastic fabric which was to be its support.

It will be seen, on a careful inspection, that the meshes, although at first sight they may appear to be in great confusion, are nevertheless so arranged as to form channels, or tubes, some large and some small, which pass in various directions through the sponge; oftentimes running into one another, and terminating at last on the outside in round apertures. These—the smaller of them more particularly—are called pores; and from this structure it is that the whole family has its name, porifera—animals with pores.

It is thought that the sponge in its living state imbibes the sea-water very much as its framework drinks up that which we press from it when bathing ourselves. The element which supplies its food seems to be absorbed by the minor tubes through the pores, by what is called capillary attraction—that curious power by which a liquid is drawn up by, or naturally enters into a very small tube, or among a bundle of filaments—and then, by the rapid vibration of certain cilia—hair-like appendages which spring from the living film—or else by the exertion of some other effort not yet understood, to be driven out again through the larger channels. At all events such a circulation goes on, no doubt for the animal's nourishment, its food being, possibly, the small marine vegetables, algæ, which float freely in the water.

The sponge seems to be propagated in more ways than one. It is sometimes reproduced by gemmules, or, as it were, buds. At the proper season of the year little protuberances shoot out from the gelatinous matter which lines the larger passages, and, in the course of time, assuming an oval form, separate themselves from the parent mass; and having in this condition, by means of vibratile cilia, the power of locomotion, as though they were allowed to travel a little before they settled down for life, they move about till they find a suitable resting-place, when, anchoring themselves to some rock or stone, they take up the position in which they are to remain stationary during the rest of their existence. It used to be the opinion of naturalists that, when sponges in their living state were cut or torn, slight contractile or tremulous movements might be observed in them; but more careful experiment seems to have produced a general conviction that no such signs of feeling can be elicited by any means.

We should have a very inadequate notion of these creatures, however, were we to suppose that they were all like the sponge of commerce just described. There is not only a considerable variety in size and form among them—some being very small and others of large dimensions, some being fan-like, others branching irregularly, while others again, as most persons know, are spherical, or chalice-shaped—but there is, also, a great deal of difference in their internal constitution, for while one kind secrete nothing but a wool-like maze as their skeleton, others are able to produce a perfectly rigid frame of lime or flint, which, when cleared of its gelatinous covering, has been compared to a mesh-work of spun glass.[1]

But in addition to this support, many sponges are furnished with spicula, or spines, either of lime or flint, which are so placed in the living jelly as to impart to it a considerable degree of firmness. In some species the sides of the larger canals are studded with these spicules; in others they make up nearly the whole of the framework itself; and they are not very uncommonly found under both these conditions in the fossil sponges of the chalk-flints. For these harder and less destructible parts would be likely to remain though the softer portions of such organisms had disappeared: and they have accordingly been frequently preserved.

There is very sufficient proof that sponges were most prevalent in the sea of the Chalk; and the presence of these spicules in large numbers in the chalk itself, and in the flints which come from it, confirms the fact.

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[1] Mantell, *Medals of Creation*, p. 250.

Their forms are various; and some of them are of great elegance. A glance at Pl. I., Fig. 2, will give a better notion of them than could be conveyed by any verbal description. The most common among them is the acicular spicule, straight or curved, as at *p*; and the next in abundance is the tri-radiate, as at *h*. This last is usually figured as if it consisted of nothing more than three spines radiating from a centre, and so it commonly appears when floating in the flint; but in general—perhaps always when it is complete—it has a fourth, and longer shaft, which springs from the point at which the other three unite, at right angles to them, as at *f*. The same may be said of the forked tri-radiate spicule, *g*; which is seen in its perfect form at *e*. The star-shaped spicule, *l*, has also a shaft from the centre. These three may be likened to nails with ornamental heads. The spindle-shaped spicule, with raised rings, *o*, is far from uncommon; the more finished form of it, with a tri-radiate summit, *n*, is of rarer occurrence. Of certain globules, to be described hereafter, as hardening the integument with which, in some instances, the animal is covered, there are unnumbered fossil specimens, both in the chalk and in the pebbles—they are themselves usually of flint. The spined globule, *i*, is of very small size; and on that account, perhaps, frequently escapes detection. The remaining forms present themselves occasionally.

The observations of Professor Williamson[1] upon spicula found by him in the white mud of the Mediterranean—modern chalk—the remains of sponges living at present in that sea, several of them being precisely like those in the flints, apply so directly to the elucidation of the nature of these bodies, that they may be well introduced here. "The most common among them," he says, "is the calcareous tri-radiate. It occurs in many living species. The siliceous acicular spiculum is also abundant; sometimes with one end thickened like the head of a pin, at others pointed at each extremity. The latter is the most common form.

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[1] *Mem. of Manchester Phil. Soc.*, vol. viii., *New Series.*

Spicula occur which, probably, belong to some species of *Tetheia*. In the fibro-fleshy texture of this sponge there are bundles of spines which radiate from the centre to the circumference, some of them passing through the thick skin, or rind. In the latter are bundles of shorter spicules; and in the interstices between them are sparingly scattered minute stellate siliceous bodies of great beauty, resembling in form the bossed iron balls hung by a chain to the war club used in the early ages." "I have also found a considerable number of small siliceous balls, which belong to some species of *Geodia.* In this, as in *Tetheia*, we meet with long radiating spicula, but with the external extremity often divided into three recurved points like grappling-irons. The skin, or outer crust, is dry, and consists of an aggregation of small siliceous globules, cemented together by an organic mucus, so as to form a solid pavement." "By what mysterious process," continues the professor, "the simple textures of the sponges have the power of throwing into such exquisitely beautiful forms the silica obtained from the waters of the ocean, it is impossible to say. The manner in which each species preserves its own, in many instances peculiar form, indicates that there is some apparatus for effecting the object which has as yet escaped detection."

When we have acquainted ourselves with the spicules preserved in the flints, whether floating in the transparent mass, or loose in the cavities, and have seen them so continually associated with the beautiful network of these organisms, and have then compared them with those from the chalk, and learn, from such observations as those of Professor Williamson, that the identical forms, supplied by decaying sponges of the present time, are being deposited in a very similar substance at the bottom of the Mediterranean, we shall at least have no doubt of the origin of the fossils before us: we shall be convinced that they are the remains of similar animals which, ages ago, were inhabitants of the chalk sea; for the flints of our surface soil could have had them from nowhere else.

Plates II. to *X.*—FORAMINIFERA,[1] or Polythalamia.[2]—These beautiful little creatures, the remains of which are the most varied, as they are the most interesting of these microscopic fossils, demand a more detailed notice.

"Zoologists," says Professor Williamson in the paper quoted before, "have long been acquainted with the existence of recent and fossil forms of microscopic chambered shells from almost every European country." It may be as well to notice here that they are exclusively marine; none of them have ever been detected living in fresh water, or fossil in a fresh-water deposit.

"In 1732," he continues, "Breyn pointed out the resemblance between many of these forms and the recent Nautilus; which view was also adopted by Gesner." The recent, or still living mollusk here referred to, is the Pearly Nautilus—*Nautilus Pompilius*—whose large and beautiful giraffe-striped chambered shell is so well known as an ornament for the mantelpiece or chiffonier. The inner layers of this shell are of mother-o'-pearl, while the outer part is not unlike porcelain in appearance. The ingenious Chinese take advantage of this structure, and carve a variety of patterns out of the more opaque portion, leaving the shining mother-o'-pearl underneath to relieve them; or else, clearing away the upper layers altogether, they engrave their figures on the smooth surface left. In one or other of these conditions, or sawn through the middle to display the gracefully curved chambers, it must be familiar to most persons. A glance at one of the halves of the shell will be sufficient to convince any one that it was a mistake which the earlier zoologists were likely to fall into when they concluded that the foraminifera, resembling it closely in appearance, were nearly allied to it.

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[1] FORAMINIFERUM,—an animal having foramina, or holes, through its shell. The shell in many species is pierced all over, like a colander.

[2] POLYTHALAMIUM,—an animal occupying a shell of many chambers.

But however similar these shells may be in their general outline, and in their division into chambers, there is no kind of connexion, or even likeness, between the animals which inhabit them. The Nautilus is one of the cephalopodous mollusks, or cuttlefishes; among the most highly organised of shell-fish, therefore; while the foraminifera are thought to be akin either to the infusoria—animalcules which breed readily in vegetable infusions; or to the bryozoa—moss corals—an order of polypes; and certainly occupy a very far lower place in the scale of creation than the Nautilus.

Nothing, however, was certainly known of the true character of these minute creatures until a few years ago. M. Dessalines D'Orbigny, who gave much time to the consideration of them, adopted the opinion that they were nautili, and included them in his classification of the cephalopods. He ascribed to them an external animal, bearing the form of a sepia—one of the cuttlefishes—the little shell itself being regarded by him as an internal bone.[1]

The Spirula, which is a cephalopod, has a chambered shell, not unlike that of some of the foraminifera, encased within the soft parts of its body, and serving the purpose of a bone; and because the shell of the foraminifera has not a large open mouth, like the Nautilus, but seems, to those who examine it improperly, to be everywhere closed, like the bone of the Spirula, so that the animal inhabiting it could have no communication with the element in which it lives, M. D'Orbigny thought that it was likewise an internal shell; and so, reasoning from analogy, he concluded that the creature which owned it was a cephalopod allied to the Spirula.

M. Dujardin was one of the first who studied these little animals with any success. He placed them among the infusorial animalcules. He conceived that, like the Amœba, one of the lowest of that class, they consist of an animated slime, capable of extending itself through the foramina, or pores of the shell, into pseudopodia, or false feet, looking upon their filiform processes—to be hereafter particularly described—as organs of a similar character.

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[1] Professor Williamson, as above.

Opinions were thus divided, when the subject received additional light from the investigations of Dr. Ehrenberg, the celebrated microscopist of Berlin. He proved that the foraminifera, or polythalamia, as he calls them, have no connexion whatever with the Nautilus, and that their shells are not internal bones. "It is at once evident," he says, "that there is no outer body surrounding the shell, but only an interior soft one;"[1] and he thinks that the animal itself is related to the bryozoa among the zoophytes. "When," he says, "Dujardin, calling them by the new name of Rhyzopodes, expressly compares the polythalamia to the Proteus—Amœba—of the infusoria; such an association cannot be admitted, unless it be first proved that a polygastric structure exists in those bodies."[2]

His reasoning, however, has not been considered very convincing. "Authors agree on the whole with Dujardin," say the editors of the Micrographic Dictionary, so lately as in 1855.[3] "He views the foraminifera as allied to the Arcellinæ," a family of infusoria, some of which correspond to the Amœbæ which are contained in a carapace, or shell. From an aperture in the siliceous case of these Arcellinæ, one or more flattened expansions are protruded, which, of course, resemble in some degree the tentacles, or filiform processes, which, as will be shown presently, issue from the sieve-like shells of so many of the foraminifera. These organisms, then, it may be concluded in the words of the Micrographic Dictionary, "are so imperfectly known, that little can be laid down with certainty concerning their systematic relations."

Any one engaged in these pursuits who desires to enlarge his acquaintance with the forms of these most beautiful little shells, may find a considerable variety of them among the sand which comes in the sponges from the Mediterranean. When those who deal in sponges buy a new stock, they are sure to have a quantity of sand with them, which is sometimes full of well-preserved specimens of foraminifera. Not a few of them may be obtained from the sea-weed—the more delicate kinds especially—which is thrown up on our own shores; and even the dirt which adheres to the shell of an oyster will occasionally supply a species or two.

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[1] *Scientific Memoirs of Foreign Academies*, Vol. III. part x. page 342.

[2] *Magaz. Nat. Hist. July* 1841, p. 386.

[3] Article "*Foraminifera.*"

A good general idea of the character of the whole family may be formed from an inspection of the *Rosalina Beccarii*, a foraminifer abounding on the coast of Essex, which may be easily kept alive in sea-water. This animalcule (Pl. X., Figs. 41 to 44) when deprived of its shell (Fig. 43) may be seen to consist of a round ball—which is the original germ—and several other joints—in this case nineteen—which have been added to it, each new one being larger than the one which preceded it. They are united by a single tube, somewhat like the sipho of the Nautilus, which passes from one chamber to another through the whole series. It is not meant, however, that the tube of the foraminifers and that of the Nautilus are similar in anything but appearance. The Nautilus occupies only the outermost chamber of its shell, while the sipho maintains its place through all the other empty chambers, which the animal partitions off behind it, as it grows too large for the smaller part of its habitation. The foraminifers, on the contrary, leaves no part of its shell unoccupied; but when it has filled up one chamber, adds a new one. Its tube, therefore, is the connecting link of its several joints; what more it may be is not known.

As Ehrenberg says, the later formed, or larger divisions of the animalcule, are less opaque than the others. This difference is more apparent before the shell is taken off than afterwards; perhaps because the walls of the larger chambers are thinner than those of the smaller, and therefore have less colour in them. There are granular patches of a darker hue here and there in the substance of the animalcule (which are shown in Fig. 43); and from these spots proceed occasionally tubes, by which oval sacs—supposed, mistakenly, as is thought, by Ehrenberg to be egg-sacks—are connected with the pierced shell (Fig. 44).

These purses, several at one time, may grow indifferently, as it seems, from any like number of chambers, whether small or large, if, perhaps, the original ball be excepted; and they may proceed, moreover, from either face of the shell, the upper or lower. The sac and its tube are membranous, and when the shell is dissolved they continue unaltered, and attached to the membranous remains of the shell. They do not appear in the fossil state: from their perishable nature they were not likely to be so preserved. Ehrenberg says that they are protruded in a soft condition, like frog-spawn, and afterwards swell and harden. There seems little doubt that they have something to do with the reproduction of the animalcule: a very large proportion of the dead shells found in the early summer have such sacs attached to them.

In some kinds of recent foraminifers the joints or chambers are connected by several tubes, instead of having but one, as in that just described. The fact is certain, but the meaning of the structure so indicated is not understood. The distinguished investigator so often referred to thinks that, in such cases, there are as many different animalcules, packed one over the other, as there are tubes passing through the partitions of the shell; so that it is a polypidom, or habitation of many polypes associated together, which is not unfrequent with such organisms. But Professor Williamson has shown—and it is sufficiently obvious upon proper examination—that the number of the passages is greater as the animalcule adds to the number of its chambers. This seems irreconcilable with Ehrenberg's hypothesis; since, to fulfil the conditions of it, there ought to be as many animals, and, therefore, as many tubes, in the smaller as in the larger chambers. Whether these Polysomatia—many-bodied animals—as Dr. Ehrenberg calls them, were peculiarly scarce, or had no existence in the Chalk sea, it is not possible to say; but among a large collection of fossil specimens no such structure is visible, although the single tube is often well preserved, and very conspicuous.

Fig. 41, Pl. X., represents the living animal, *Rosalina Beccarii*, in its sieve-like shell, the under surface being towards the observer, as it was attached to the side of a test-tube by bundles of long branching filaments thrust out through the foramina—minute holes—with which the shell is everywhere pierced, the only other opening, as is usual in this family generally, being a much larger, though still small aperture in the otherwise closed mouth of the shell (see Fig. *a*, *C*, Pl. VIII., *x*). These filiform processes work backward and forward, among and over one another, without entanglement, although they are greatly finer than the web woven by a young spider. Occasionally one of them, instead of being drawn straight in, appears to be brought round by some means or other, as at Fig. 41, Pl. X.; and after having reached the side of the shell, perhaps, it disappears through the minute tube appropriated to it, without any interference with those tentacles across which it must pass in its way back again. This is strange if these filaments are merely slime, without any proper integument.

The bundles of filiform processes are represented in the plate as though they came from the margin of the shell, or from its upper surface only. This is not so: they are protruded from all parts of it, sometimes in one direction, and sometimes in another. As, however, in consequence of the transparency of their texture, they were not easily traced to the exact spot whence they issued, they were drawn as they appeared to the eye.

The use they make of these tentacles while in the test-tube is not only for attachment and locomotion, but for covering themselves over with a thick coating of the flocculent sediment of the sea-water. For this they fish unceasingly, dragging up to their sides every little particle within their reach, until they are completely hidden in it. It can hardly be that they take all this trouble because they do not like exposure to the light, for they choose to work their way out of the sediment at the bottom of the vessel in which they are kept; and they go on with this labour if placed in the dark. They may, perhaps, provide this covert to entice and detain their prey, as infusoria and diatomaceæ betake themselves to it, and harbour in it in abundance; or it is not impossible that the decaying matter thus collected may itself be their food.

Their locomotion is chiefly by jerks; suddenly disengaging from the glass all the filaments which are extended in one direction, they are drawn along quickly, though for a very short distance, by those that are stretched the other way. When once covered well up in their favourite sediment, however, they do not seem to have much inclination to travel. Occasionally the processes may be seen—as at Fig. 42, Pl. X.—radiating from all parts of the shell, and undulating freely with any motion of the water.

There is an animalcule, the Gromia—very commonly associated with the foraminifers on our coast, especially upon the marine plants growing under water in oozy places—which in its habits, and, in one very manifest respect, in its constitution, is singularly like them. It is about the same size as the Rosalina just described, and consists of a tender membranous sac, of a spherical form, and dirty orange colour, having on the lower side a large round aperture, out of which issue here and there bundles of very slender branching threads, exactly like those of the foraminifers, but much longer in proportion, as they occasionally extend to ten times the diameter of the sac, while those of the others seldom measure four of the diameters of their shells.

It is, comparatively speaking, a vigorous and active creature; for while the foraminifer, when once covered up, seldom moves, the Gromia frequently shifts its place on the glass, and is as lively at the end of six months as it was when first captured. In the appearance and movements of the thread-like processes there is absolutely no difference between the two. The Gromia is for ever thrusting out its cobweb tentacles, which slide along the glass, in a direct line outwards, in a most surprising manner, by what power it is not easy to conceive;[1] and when they have reached their utmost extension they are drawn in again, seemingly without an object. When the little creature wishes to shift its place, it proceeds as the foraminifers do in a like case.

"Dujardin," says the Micrographic Dictionary,[2] "places this genus in the Rhizopoda—animals, with root-like feet; Ehrenberg, among the Foraminifera. It belongs to the Arcellinæ." This is assigning to it a family relationship with the foraminifers, perhaps, to which it seems to be allied, if we may judge from appearances.

From the description of the living foraminifer just given, it will be easy, from an inspection of the casts of the interior of the shell, which is what is usually seen in the solid flint, to understand the plan upon which the body of each genus was formed; for the shell was exactly moulded upon the softer parts. They all began their existence in a single cell, round or oval, as the case might be; and some of them appear to have gone no further, but to have occupied this one chamber all their lives without making any additions to it, protruding their filaments from every side around it.

Some doubts have been raised as to the existence of these one-celled foraminifers. It is hardly to be questioned, however. Numerous fossil specimens of them are to be found, which are of a much larger size than is usually attained by the first cells of the many-chambered kinds, for which they have probably been mistaken. We have given the forms of two (Pl. V., Fig. 32), represented as transparent objects. In other genera, to this first chamber many more were added, in some instances thirty at least, arranged in a great variety of forms; but whether placed end to end in a straight or curved line, as the *Dentalina* (Pl. IV.,

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[1] Can the processes of the foraminifer and gromia be extensile tubes closed at the end, into which the animalcule forces water which it draws in through the larger aperture?

[2] Article "*Gromia.*"

Fig. 21); or spirally coiled, as the *Rosalina* (Pl. II. Figs. 3 and 4); or partly spiral and partly in a straight line, as the *Flabellina* (Pl. III., Fig. 18); or branching in a zig-zag manner alternately right and left, as the *Textularia* (Pl. III., Fig. 13); or partly so branching, and partly coiled, as the beautiful fossil, Pl. III., Fig. 15, there represented, in its clear flint shell, as a transparent object; or advancing to their full growth upon whatever other plan, they all agreed in beginning with one round or oval chamber, from which others proceeded of a gradually increasing size.

The plates of the Foraminifers may now be explained; and for facility of reference they will be taken in the order in which they are numbered, although in one or two instances it will be attended with the inconvenience of separating species which are thought to be of the same genus.

Those figures which have a *C* in addition to their number, represent fossil animalcule shells from the chalk of the same species as those from the flints which have the same number without the *C.* These latter show the form of the animalcule when deprived of its shell; just as the *Rosalina Beccarii* is figured, Plate X., Fig. 43. Not that the fossils in the flints are actually casts of the body of the animalcule; but inasmuch as they filled the shell, which was exactly moulded on its body, they are in effect casts of it. They are really inclosed in a cast of the shell; but it is of such very transparent flint that it cannot be seen, except under peculiar circumstances. The spaces, therefore, between the several chambers, give the thickness of the shell.

PLATE II.

Fig. 3, *Rosalina Ammonoides*—under side—in the substance of the solid flint.

Fig. 4, Upper side.

The shell of this genus is coiled obliquely, like that of the snail; not on one plane, as is the shell of the ammonite.

The figures are from different specimens, as one side only can be seen of those which are immersed in the flint. It will be observed that these specimens are coiled in different directions. Quite as many of the foraminifers of the same species turn from left to right as from right to left: it seems to be a matter of indifference with them. This is a common species.

See Plate VIII., Figs. 3 *C*, 4 *C*, and *a. C.*

Figs. 5 and 6, *Globigerina cretacea*, like the preceding, in solid flint.

These are varieties of the same species, 5 being coiled less obliquely than 6: specimens may be found of every form between the one and the other. The chambers are globular, with a cup-like depression on one side, where each was moulded against that which preceded it.

These are both of very common occurrence.

See Plate VIII., Figs. 5 *C* and 6 *C*.

Figs. 7 and 8, *Cristellaria rotulata*, in solid flint.

Elongate and compact variety of the same species.

These differ from the preceding, in being coiled upon the same plane, like a rope, the second circle of chambers being perpendicularly over the first, as they are in the ammonite, without any obliqueness.

It will be observed that the connecting tube is not shown in Fig. 8. Most commonly it is not preserved in the flint fossils.

This species is not uncommon.

The genus very considerably resembles the Nautilus; but like all the other foraminifers, it is distinguished from that mollusk by the make of the shell. The septum, or divisional wall, between the chambers of the Nautilus, is always concave, or curved inwards; that of the foraminifer is as uniformly convex, or curved outwards.

See Plate VIII., Figs. 7 *C* and 8 *C*.

Fig. 9, *Textularia globulosa*, in solid flint.

This species has spherical chambers, cupped on the inner side, like the *Globigerina cretacea*, Fig. 5; but in the Textulariæ, the mode of growth is changed. Instead of a spiral, a zig-zag line is adopted, the chambers branching right and left.

This is a very abundant species.

See Plate IX., Fig. 9 *C.*

Fig. 10, *Textularia turris*, in solid flint.

The chambers follow the same line as the last: the curve is a mere accident; it is very usual to find the foraminifers distorted in their growth.

A section across this species would show a somewhat flat-sided oval.

Not uncommon.

See Plate VIII., Fig. 10 *C.*

Fig. 11, *Textularia obsoleta* (?),[1] in solid flint.

This species is quite flat on both the upper and under sides; or rather concave perhaps. It is not very uncommon.

See Plate VIII., Fig. 11 *C.*

Fig. 12, *Textularia* or *Polymorphina* (?), in solid flint.

Whether this is a Textularia or not is uncertain: it evidently follows the zig-zag mode of growth. The section would be perfectly round.

See Plate VIII., Fig. 12 *C.*

PLATE III.—FRONTISPIECE.

Fig. 13, *Textularia aciculata*, in solid flint.

Section, a very narrow oval.

Fig. 14, *Textularia aciculata*—variety (?)—cast of shell from cavity in flint.

This specimen is a cast of the shell in transparent flint, the chambers being filled with opaque matter, probably chalcedony. It is from a cavity in a flint pebble. It is figured as it appears when viewed as a transparent object, fixed, in Canada balsam, between two glasses.

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[1] A distinguished naturalist and geologist has been consulted about the names of these microscopic fossils. They have been so little studied that in determining the genera and species much difficulty has been found. Some of those here represented have probably not received names; and it is believed that few of them have been figured as they appear in the flints. Where there seemed to be a doubt about the species, a note of interrogation is appended to the name.

Not uncommon.

Fig. 15, *Textularia anceps* (?), cast of shell from cavity in flint.

This can hardly be a Textularia. It began life in the form of a Cristellaria (Fig. 7); and having completed one coil, it changed its mode of growth to that of a Textularia. There are at least three species, if not four, of this genus. Section lozenge-shaped, each chamber having the form of a laundress's flat iron.

By no means common.

See Plate IX., Fig. 15 *C.*

Fig. 16, *Rosalina marginata*, in solid flint.

This species is nearly flat-sided: it may be only a variety of 5 and 6. A series may be easily collected passing from *Globigerina cretacea* to this form, without a perceptible distinction between any two adjoining specimens.

Common.

See Plate IX., Fig. 16 *C.*

Fig. 17, *Rosalina Ammonoides*, cast of shell from cavity in flint.

This is quite a young specimen; and, if the right name is assigned to it, of unusually large size.[1]

See Plate II., Figs. 3 and 4; and Plate VIII., Figs. 3 *C* and 4 *C.*

Fig. 18, *Flabellina rugosa*, in solid flint.

This curious animalcule was at first like a flat-sided Cristellaria. At a certain stage of its growth it doubled the size of the addition which we should have expected it to make to its habitation, by giving to the new chamber the form of the letter V, and so continued to build to the end.

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[1] Throughout the whole of the foraminifers, there is an extraordinary difference in the size to which the same species will attain.

It is quite flat-sided, and thin in proportion to its breadth.

It is not common.

PLATE IV.

Fig. 19, *Frondicularia Archiaciana*, in solid flint.

Method of growth like the last, except that it began with the V-shaped chamber immediately upon advancing from the germ.

It is not common.

Fig. 20, *Frondicularia angulosa*, in solid flint.

This species had the peculiarity of forming its second chamber of a much larger size than those which followed.

Not common.

Fig. 21, *Dentalina communis*, in solid flint.

This fossil is cylindrical, and always curved.

See Plate VI., Fig. 33, and description there.

It is not uncommon.

Fig. 22, *Vernouilina*, flint cast from cavity in flint.[1]

This has the form of an inverted pyramid, with three flat sides of equal size.

Its mode of growth was more elaborate than that of those already described. Beginning, as usual, with a ball of somewhat irregular form, it added a course of three triangular wedge-shaped chambers, one after the other, so placed that the last-formed covered the proper proportion of the upper side of the one which preceded it. In each of the successive courses the three chambers were in this way arranged precisely under the first three, except that, as they increased in size, the inverted pyramid grew wider. The aperture in each chamber is in the middle of its inner side, and, therefore, vertically under the ball.

It is not very uncommon.

See Plate VI., Fig. 38, and further description there.

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[1] It is worth notice, that these casts from the flint cavities are best seen when placed in a drop of clear water; as are those also from the chalk.

Fig. 23, *Nodosaria*, in solid flint.

The globular chambers of this species are all very much more of a size than is usual in the foraminifers: they are not cupped on one side like those of *Textularia globulosa.*

This species is sometimes of much larger size.

Not very common.

See Plate IX., Fig. 23 *C.*

PLATE V.

Figs. 24—26, *Rotalina nitida* (*umbilicata ?*), in solid flint.

From these three figures, the construction of this animalcule will be easily understood. Fig. 24 gives the base or lower side, and shows the mode in which the chambers are coiled. Each chamber is nearly of the form of one of the divisions of an orange, and a little higher than the one which preceded it, as in the profile, Fig. 25. Viewed from above, the larger chambers are seen to overarch, and nearly conceal the smaller, as in Fig. 26. This last is a specimen of much smaller growth than the two others.

It is a common species.

Fig. 27, *Rotalina Micheliana*, in solid flint.

In general character this is like the last; but the base is perfectly flat, and the foot of each chamber is slightly keeled, or has a prominent edge.

It is not at all uncommon.

Fig. 28, *Nonionina compressa* (?), in solid flint.

This is coiled obliquely, and in its general mode of growth like the *Rosalina Ammonoides*, Plate II., Figs. 3 and 4.

Common.

Fig. 29, *Bulimina variabilis*, cast of shell in flint, from cavity in pebble.

The growth of this genus, like that of *Vernouilina*, is by a succession of wedge-shaped chambers; arranged in this case, however, in a conical instead of a pyramidal form. The shape of the chamber is seen at Fig. 29 *b*, the notch in the thinner edge showing the position of the aperture.

This is a very irregular grower, as its name, *variabilis*, imports.

It is common.

Fig. 30, *Bulimina intermedia*, in solid flint.

This grows like the preceding; but the chambers are heart-shaped, and so arranged as to give the animalcule the form of an ordinary spiral shell.

It is not uncommon.

Fig. 31, *Vernouilina*, in solid flint.

This figure represents one flat side of the species before described, Plate IV., Fig. 22.

PLATE VI.

The purpose of this plate with the dark ground is to exhibit the fossils as they are seen floating in the flint.

Fig. 33, *Dentalina communis.*

This is the same species as is figured Plate IV., Fig. 21. Here it happens to be broken through the middle longitudinally. The thin, dark line is transparent quartz, which has replaced the shell. The inside is filled up with a light grey flint, the enveloping flint being of a darker grey. It is evident that every additional chamber clasped the one which preceded it, thereby giving much strength to the shell.

Fig. 34, *Textularia trochus.*

This species, like the Trochus among mollusks, is conical;[1] the chambers, which are semicircular, are formed alternately right and left, in a zig-zag line, as are those of the other Textulariæ.

The specimen figured needs a little explanation.

It is represented as it appears immersed in the dark flint, the shell-space, which is narrow, showing as a thin, dark line. The eight earlier chambers are entire. From the other seven a portion is broken, exhibiting the interior. The white part is the milky chalcedony which first probably encrusted the inside of the shell, and became more transparent towards the middle of the chamber, where of course it would look darker. This is very generally the manner in which the interior of these fossils is filled.

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[1] It is the usage among naturalists to figure the foraminifers with the earliest formed chamber downwards; so that when they are compared with the corresponding forms among the mollusks, they appear to be inverted.

The species is common.

Fig. 35, *Amphistegina* (?).

This species, though small, is distinguished by the unusual number of its chambers. It is coiled obliquely.

Not very common.

Fig. 36, *Vernouilina.* Genus as before, see Plate IV., Fig. 22.

This individual shows the same peculiarity of growth as the fossil to be next described, though less conspicuously: it is of a different species, however, and not common.

Fig. 37, *Vernouilina tricarinata.* Genus described before, see Plate IV., Fig. 22.

This curious specimen exhibits very plainly a mode of growth which individuals adopt occasionally when they have attained a considerable age. Having followed for many courses the triangular form, they leave it, to adopt the simple zig-zag of the Textulariæ. The last eight or nine chambers have been so added in this instance. Part of the side of this portion of the fossil is broken away, as in Fig. 34.

Fig. 38, *Vernouilina.*

This specimen, mineralized in a manner which is very rare, exhibits one of the sides of a *Vernouilina*, of a different species from that last described; but probably the same as that figured Plate IX., 38 *C*, though of larger growth. It is immersed in the dark flint, having undoubtedly, as a substitute for its shell, a casing of clear quartz, though it cannot be rendered visible. Through this quartz run innumerable threads of milky chalcedony, which were formed in the foramina with which the original shell was pierced. Although these filaments are not here shown scattered over the surface of the fossil—as they would require a dark ground to display them—they may be discerned, in fact, radiating from all parts of it, like the fine hairs upon a leaf. The reason why they are so much longer on one side than the other is, that in the one case they pass through the whole thickness of the keel, with which each angle of the shell is furnished; while in the other, they traverse the shell in its thinner portion only: the fracture of the flint happened to be at a slight angle to the face of the fossil, by which means the keel on one side was carried away altogether. It appears that, from the sharp edge of the wedge-like chambers, filaments of considerably larger diameter were protruded, than from the other foramina.

Plate VII.

Fig. 39, The field of the microscope, with the finest part of the dust from a cavity in a flint pebble, prepared with Canada balsam: the mere shapeless fragments are omitted. The fossils are flint casts, with opaque matter in the interior.

Fig. 39 *C*, The same, with the finer washings of chalk. The fossils here are casts of the empty shells in carbonate of lime. In both cases, the specimens are of those species which are most prevalent, and are either young, or of very small size: *Globigerina cretacea*, *Textularia globulosa* and *aciculata*, *Rosalina Ammonoides*, and *Orbulina universa*, will be recognised: the two spindle-shaped objects are very minute sponge spicules.

Fig. 40, The size of the above field.

PLATES VIII. AND IX.

Specimens from the chalk of the same species as those from the flints already described, the same number showing the same species.

PLATE VIII.

Fig. 3 *C*, *Rosalina Ammonoides*, lower side.
„ 4 *C*, „ „ upper side.
„ A *C*, Front view, showing the position of the aperture *x*.
„ 5 *C*, *Globigerina cretacea*, variety with margin.
„ 6 *C*, „ „ „ without margin.
„ 7 *C*, *Cristellaria rotulata*, elongate variety.
„ 8 *C*, „ „ compact variety.
„ 10 *C*, *Textularia turris*.
„ 11 *C*, *Textularia obsoleta*. This species is keeled on the edge of both the upper and under sides.
„ 12 *C*, *Textularia*, or *Polymorphina* (?).

PLATE IX.

Fig. 9 *C*, *Textularia globulosa*.
„ 15 *C*, *Textularia anceps* (?).
„ 16 *C*, *Rosalina marginata*.
„ 18 *C*, *Flabellina rugosa*.
„ 20 *C*, *Frondicularia angulosa*.
„ 23 *C*, *Nodosaria*.
„ 38 *C*, *Vernouilina*, see Plate VI., Fig. 38.

PLATE X.

Figs. 41—44, Recent foraminifer—*Rosalina Beccarii*.

Fig. 41, Animalcule with the tentacles fully protruded, and adhering to the glass tube.

Fig. 42, Animalcule with tentacles, or filiform processes, playing freely in the water.

Fig. 43, Body of the animalcule, the shell having been removed: four granular spots are visible.

Fig. 44, The empty shell, as a transparent object, with membranous sac attached: for explanation, see the next figure.

Fig. 45, Empty shell of recent foraminifer, *Textularia*, rendered transparent by means of Canada balsam, and highly magnified – 250 times, linear.

It will be noted that, in the centre of the shell, the foramina are seen as nothing more than round holes. This portion of the object being exactly under the eye of the observer, he looks perpendicularly through the perforations. As they recede further from this point, he begins to see the tubes rising through the shell; and, viewed in perspective, they look, of course, as though they radiated from the centre. At the circumference, he sees them in their whole length as they pass through the entire thickness of the shell, which is there displayed to him. Those among them which appear to fall short of the outside, are such as, not being exactly at the circumference, are seen, like those nearer the centre, in a foreshortened position.

Fig. 46, Fish scale: impression in flint.

Fish scales are very abundant in some flints. The substance of the scale has disappeared; but it has left its form upon the smooth material as if engraven by the most skilful lapidary. The upper part of this kind of scale is formed of concentric plates; and the margins of these plates look like so many concentric lines. This gives to some specimens a very beautiful appearance.

Fig. 47, *Spiniferite.*

These minute objects, which are very abundant, can only be well seen in very thin chips of flint, rendered transparent by means of Canada balsam, and viewed under a high magnifying power. They were formerly thought to be the siliceous cases of animalcules, and were called Xanthidia. More recent investigations have led to the opinion that they are the fossil remains of the sporangia—vessels which contained the spores or seeds—of certain kinds of Desmidiaceæ. If so, they represent vegetable, and not animal organisms; as the Desmediaceæ are Confervoid Algæ, very simply constituted plants which live in water, or on damp surfaces. The Desmidiaceæ are now common in sea-water; and if its true character is assigned to the Spiniferite, they must have been at least equally abundant in the water of the Chalk sea. They vary considerably in form; and are many of them very beautiful.

PLATE XI.

Figs. 48—50, Different forms of *Ventriculite.*

This fossil, popularly called fossil mushroom, from its occasional likeness in outline to that kind of fungus, is extremely common among the siliceous nodules of the chalk, and correspondingly frequent in the flint gravel. Although varying much in shape and size, it may usually be recognised at once by the indented margin, or ring, which surrounds the upper and wider part, and the holes which pierce the lower extremity or root.

Dr. Mantell,[1] after long and persevering inquiry, discovered the true nature of the organisms which these fossils represent. He obtained perfect specimens from the chalk, which convinced him that the original of them were flexible polyparia—the habitations of compound polypes—their form being that of an inverted hollow cone, with a suddenly widening mouth, in general figure and proportions not very much unlike the flower of our common convolvulus or bindweed. On the outside, this cone was reticulated, the meshes of the network being rather large; while the whole of the inside was dotted over with the cells—small pits or depressions—in which the individual polypes had their dwelling. From the lower, or narrow, end proceeded several root-like processes, by which the polyparium was attached to the bottom of the sea.

This cone, then, the flint invested on all sides, filling up the cavity in the middle, and usually leaving no part of the peculiar texture of the polyparium visible except round the indented edge. Not very unfrequently, however, in the flints in the chalk-pit, and occasionally even in those from the gravel of the Drift, more of the original form may be discovered, upon carefully breaking away the outside; though it is obvious that such hollow specimens were little likely to pass uninjured through all the movements which the gravel has experienced, and they are, accordingly, rather rare. But even in those which are solid, something of the general outline of the polyparium may often be seen, marked out by a different colour in the flint.

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[1] *Medals of Creation*, vol. i. p. 269.

Perhaps it may be desirable to add a few words in explanation of the nature of such polyparies.

Polypes are either simple or compound.[1] The Hydra, a minute creature, common in clear ponds, will give a good idea of the simple polype. It consists of nothing more than a gelatinous sac, having at one end a mouth surrounded with moveable threads, or tentacles, and at the opposite end, a sucker. Its tentacles serve for the capture of its prey; and it is sufficiently adroit in the use of them, twisting them about in every direction, and seizing upon any suitable substance that comes in its way, being extremely voracious. The sucker answers two purposes: it affords to the animal the means of fixing itself to any stationary object—such as the leaf of a water-plant—when it is at rest; and is used as a float when it desires to swim. Such is a simple, free polype.

There are other simple polypes, of much larger size, which secrete a more or less rigid skeleton, in the manner of the sponge; but of these it is not necessary to speak here. It is the compound polypes with which we are concerned. These consist of a number of animals, not only associated, but actually united with one another, so that one living bond ties the whole together into what has been called a compound unity. Each polype, impelled no doubt by ordinary appetite, feeds, not exclusively for its own advantage, but for the benefit of the whole ; since all are equally dependent on the gelatinous thread or film which unites, and on the polypary which supports them.

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[1] *Mus. of Anim. Nat.* vol. ii. p. 410.

Some of these compound polypes secrete, as their common support, a stony skeleton : such is the red coral of the jeweller. The polype of the coral reef also—that wonderful agent in nature, which has formed numerous and extensive archipelagos in the seas of the warmer parts of the globe—secretes solid stone as its basis. With its work we are familiar, in those beautiful masses called *brain-corals*, and others more or less allied to them. In other instances the polypary is of flexible twigs, which, when in a living state, are invested with a gelatinous bark, in the cells of which the animals are lodged. But the polype of the ventriculite belonged to none of these kinds. It is supposed to have resembled more nearly the Alcyonidæ. If so, it had neither a stony nor a horny skeleton. "The substance of the polyparium, or frame-work, of this aggregation of animalcules," says Dr. Mantell,[1] speaking of the ventriculite, "appears to have been analogous to that of the soft alcyonia, and able to expand and contract." Whatever might be the precise nature of its material, the cone was pitted all over its inner surface with little depressions, or cells, in which, it is thought, the polypes dwelt. Such, at all events, is the nature of the polyparium to which the original of the ventriculite is compared.

Dr. Mantell seems scarcely consistent with himself, in describing the mode in which the ventriculites were mineralized. He says[2] that "all these flints were *moulded* in the *cavities* of ventriculites ;" and then speaks of the silex as "*permeating*" the zoophyte. The latter notion will be thought, perhaps, by those who will examine these fossils, to be more in agreement with the appearances they present. Indeed, Dr. Mantell himself says, and very truly, that "in the flints, the *substance* of the ventriculite . . . . is distinguished from the surrounding silex by a purple, reddish-brown, or pale-grey colour." The flint, then, was not merely moulded in the cavity of the polypary: it invested a certain portion of its substance, took its place, and the whole became one stone. The truth is that, in this instance, as in that of the sponges, the manner in which the animal substance was mineralized was various, evidently depending upon circumstances.

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[1] *Medals of Creation*, vol. i. p. 275.

[2] Ibid.

Figs. 51—57, *Echinites,* and their Spines.

Echinites, though by no means so abundant as the Ventriculite, are still very common fossils. The flint gravel everywhere furnishes specimens of them, either whole or in a fragmentary condition; and they are often picked off the surface of the ploughed fields wherever many chalk flints occur in the soil.

In the case of the Ventriculite, no recent species could be referred to for the illustration of its nature or history; but it is by no means so with the echinite. The common sea-egg, sea-urchin, or sea-hedgehog of our coasts—*Echinus sphæra*—may be taken as a type of the whole family. It is of a globular form, and covered with spines, as its name, urchin or hedgehog, would lead us to expect. When some of these spines are removed it is seen that the soft parts of the creature are contained in a firm crust, or box, which is studded over with small prominences, or tubercles, to which the spines are so attached by a joint that they can bend to and fro freely in any direction. By means of the spines, on which it rolls, and aided by a great number of suckers, thrust forth through certain pores in its case, the echinus is able to move about with considerable activity, climbing even the upright faces of rocks, upon which its suckers enable it to lay fast hold. It feeds on the young of crabs and shell-fish, and upon zoophytes. It is very fond of concealing itself in the sand, into which it burrows in a curious manner, by the help of its spines. In the common sea-egg the two openings, ingestive and egestive, are at the opposite sides of the animal; but the disposition of these parts varies in the different genera. Fig. 55 exhibits an Echinite with the mouth and outlet both on the base.

The case of the echinus is made up of many-sided calcareous plates (see Fig. 54), closely fitting against one another, but not agglutinated together, of such forms, oblong or otherwise, as are suitable to the particular curve or angle of that part of the shell to which they belong. And as the animal increases in size, each plate grows with it, by additions around its edge, so that the proper shape and proportions are maintained from first to last.

Everyone who has examined an echinus must have observed that the plates are so arranged as to mark out the surface of the globe they form into certain divisions. Of these the five wider, each of which consists of two rows of the larger plates, are called the *areæ*, spaces; while the five narrower, each having two rows of much smaller plates, are the *ambulacra*,—avenues or walks. These smaller plates are pierced for the passage of a vast number of tubular suckers, or tentacles, which are thrust out for the purpose of prehension, while the larger plates are studded with the tubercles for the attachment of the spines.

It is needless to say that the softer parts of the animal, such as the tentacles, have left no traces in the rocks. It is a consequence of its having been furnished with an enduring calcareous crust that its form has been so commonly preserved in various strata, for which its habit of burying itself in the sand was also obviously favourable. The fossils in which we are particularly interested are either casts or moulds of the shell, or of parts of it, in a more or less perfect state. Sometimes single detached plates, sometimes several together, are represented by a sharp impression in the substance of a flint; while at other times, though much more rarely, the complete exterior of the animal, the shell with the spines in close approximation, if not attached to it, may be seen, shadowed out as it were in one colour, while the flint itself is of another,—grey, perhaps, upon black.

But the more commonly occurring echinites of the chalk flints are of the kind figured in Plate XI. Such fossils are casts, sometimes of the outside (Fig. 55), and sometimes of the inside (Figs. 51 and 54), of the shell itself. Not uncommonly the same flint even will supply both. The empty case, having been taken possession of by the mineral, which filled it within, and invested it on all sides without, was at length decomposed, leaving in the stone an exact counterpart of its two surfaces, to the finest lines and studs. The consequence of this process was the production of fossils representing the original either in a perfect condition, or in every stage of dilapidation. Fig. 59, Plate XII., exhibits a portion of a cast of the outside of an echinus, in which the tubercles with which its surface was besprinkled have left their form so accurately impressed as to bear examination with a microscope; while, in contrast with this, Fig. 52, Plate XI., represents an echinite in which little else is preserved than the general form of the original; the details are almost entirely wanting. And specimens may be found in every condition between these extremes.

The Spines, Figs. 56 and 57, Plate XI., are of not very unfrequent occurrence in the flints. They are of various forms and sizes, and differ considerably in their ornaments. Some are slender, sceptre-like rods; while others in shape and sculpture are not unlike seeds or fruits, for which they have occasionally been mistaken. Some of the spines are very small, requiring the help of a microscope for their investigation. Of these the interior structure is occasionally elaborate, and very beautiful;

and remains of them, either whole or in broken pieces, are not uncommon in the flints. Those engaged in these researches will soon become familiar with them, either in the form of small tubular fragments, consisting of about ten slender columns, held together by a web, which is sometimes pierced with round holes, and looks like lace; or else, if they are broken across their length, and show a section of the tube, as a ring, with a circle of smaller rings surrounding it.

The echinites occurring most abundantly in the flint gravel are the following :—

Fig. 51, *Cidaris diadema* (*Diadema rotulare*).

Fig. 52, *Spatangus* (*Micraster*) *cor-anguinum.*

Fig. 53, *Galerites cretosus.*

Fig. 54, *Ananchytes ovatus*, profile—an incomplete fossil, broken out of a large flint, of which a water-worn portion (*a*) still adheres to it.

Fig. 55, *Ananchytes ovatus*, base. The five double rows of studs, though not perfect, will be seen to converge towards the oval mouth. Each of these round studs occupies the place of two of the holes which pierced the animal's shell along the ambulacra, such perforations being usually represented either by two small indentations, or by two prominences, according as the fossil is a cast of the outside or inside of the case; but here, probably from the peculiar state of decay of the echinus when taken possession of by the flint, the appearance is that shown in the figure.

Fig. 56, Spine of *Cidaris clavigera.*

Fig. 57, Spine of *Cidaris variolaris.*

PLATE XII.

Fig. 58, Hertfordshire Pudding-stone.

This is a hard conglomerate of rolled chalk flints and sand, bound together by a siliceous cement, which adheres to the pebbles it incloses so firmly, that when a mass is shattered they quite as commonly break right across as come out of their setting. Large pieces of it, of half a ton weight or more, with smaller fragments, rolled and unrolled, are found in the Drift in Hertfordshire and adjoining counties.

Fig. 59, Fragment of flint with impression of part of an echinus.

Fig. 60, *Branching Sponge:* a cast in flint.

It is partly enclosed in a flint pebble, which is not here figured, that the form may be seen more distinctly.

Fig. 61, Articulating surface of an ossiculum, or joint of the stem, of a *Pentacrinite:* impression in flint.

In the seas of the West Indies is found the *Pentacrinus caput Medusæ,* a rare and beautiful creature, allied to the star-fishes. "This animal," says Dr. Mantell,[1] "has a long jointed stem, which is fixed at its base by radicle processes, and supports a cup-like receptacle, formed of a series of calcareous plates closely adjusted to each other, in which the body and viscera are contained. The upper part of the receptacle is covered by a plated integument, in which there is an opening for a mouth. From the brim of this cup proceed five jointed arms, which subdivide into branches of extreme tenuity: the upper and inner side of the arms support numerous articulated *cirri* or feelers. The joints composing the column of support," or stem, "are pentangular, very numerous, and have a central perforation; and there are side-arms, or articulated tentacles, that radiate from the column, in groups of five, at different parts."

In a living state the skeleton is covered by the integuments which secrete it. The mouth is situated in the centre of the plated integument of the receptacle,[2] and surrounded by the five arms, which, when spread out, with their numerous cirri, form a net for the capture of their prey, and convey it to the mouth. Such is the living representative of the pentacrinite.

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[1] *Medals of Creation,* vol. i. p. 312.

[2] The receptacle in some fossil species is not unlike the seed-vessel of a plant,—of a rose, for instance,—although the plates into which it is divided are usually visible. When such specimens maintain their position upon their stalks, with the arms

"The fossil remains" of animals of this kind, continues Dr. Mantell, "consist of the ossicula, or little bones, of the column, arms, and tentacula; of the plates of the receptacle; and of the peduncle, or process of attachment, by which the animal was permanently fixed to the rock."

These remains are not very common in the chalk flints. Occasionally may be found in such a stone a pentagonal cavity, ornamented at the bottom and top in a five-leaved pattern, like Fig. 61. It originally contained one of the joints of the stem of a pentacrinite; or, if it should be divided by constrictions transverse to its length, this shows that there were as many joints enclosed there as there are marks of such division. The bone of the pentacrinite was of lime, which has escaped from its confinement in the flint, and these cavities are the result.

Fig. 62, Rolled Chalk-flint Pebble, with impression of shell.

Fig. 63, Unrolled Chalk-flint from the gravel-pit.

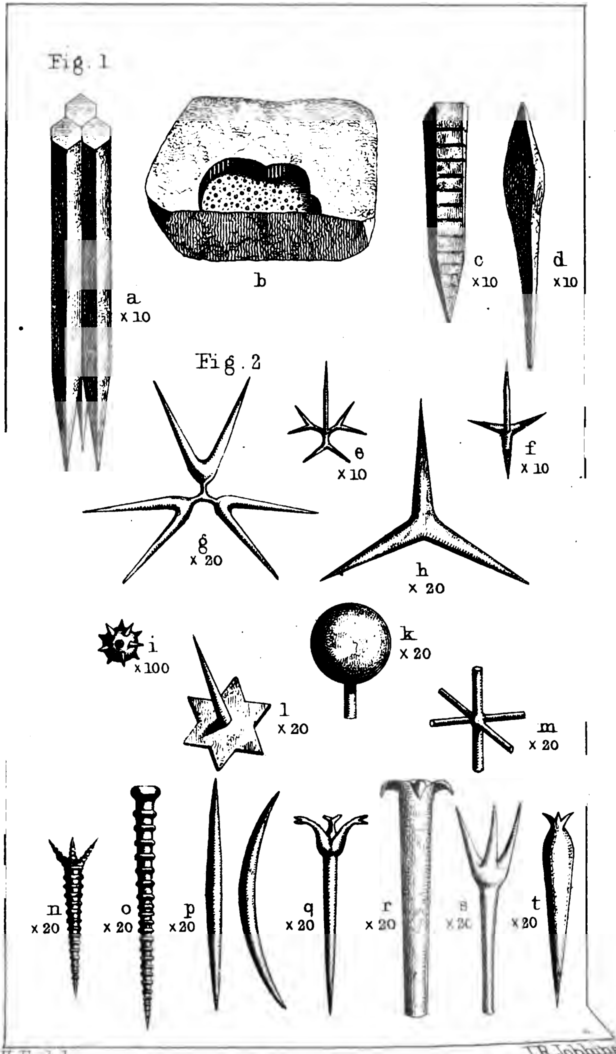
Flints of this irregular shape were most likely formed round sponges, or other decaying animal substances, of which they frequently exhibit proof.

In whatever manner they were originally brought together, however, they have preserved within them innumerable fossil remains, fraught with instruction for those who will reason upon them: some of the truths they teach it has been the aim of this little book to unfold.

closed, they are so much like flowers that they are popularly called "stone lilies." This name, however, is now restricted to such of these fossils as have round stems,—the *encrinites,*—while those with angular columns are named *pentacrinites.*

R. CLAY, PRINTER, BREAD STREET HILL.

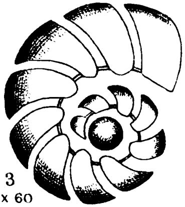
Plate 1



H. E. del

J.R.Jobbins

Plate II.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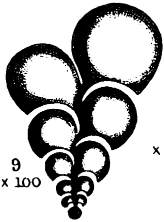
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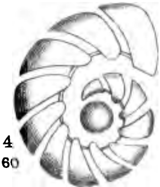
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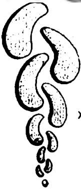
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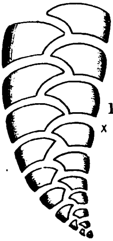
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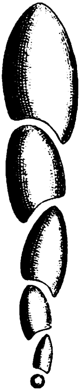
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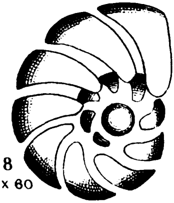
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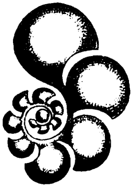
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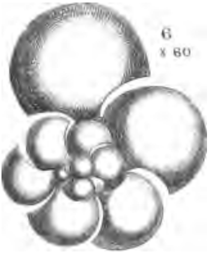
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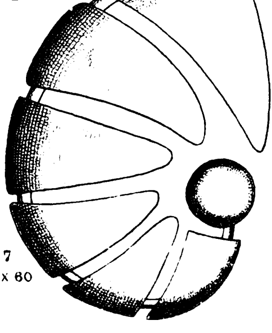
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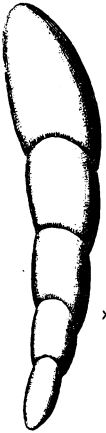
Plate IV.



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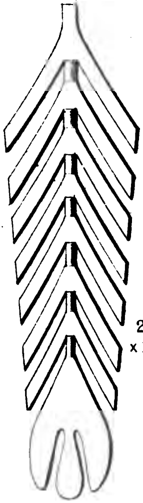

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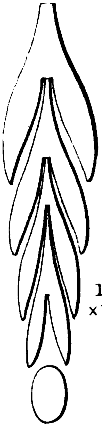

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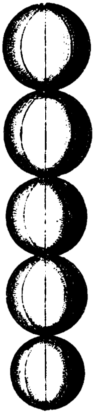

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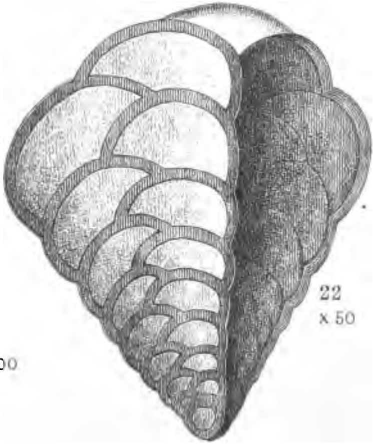

22
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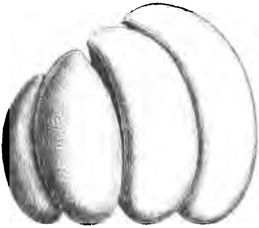
Plate V.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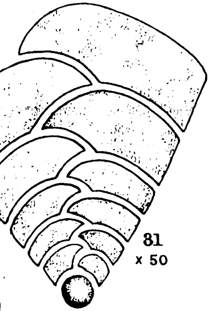
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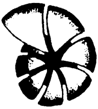
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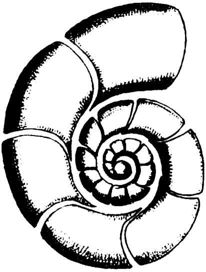
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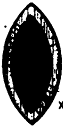
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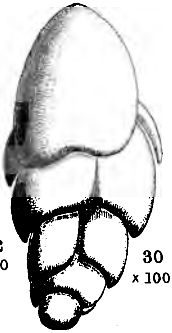
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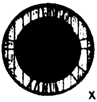
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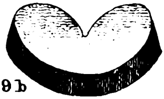
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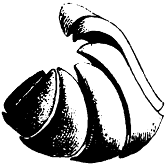
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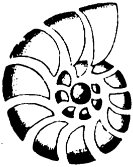
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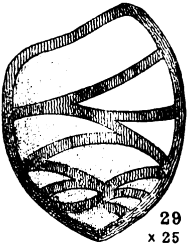
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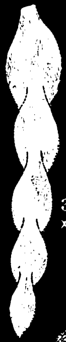

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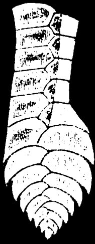

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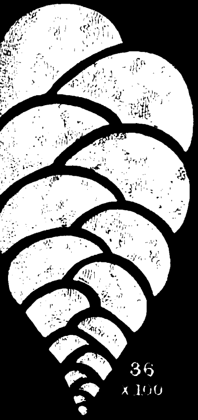

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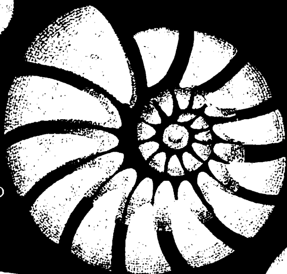

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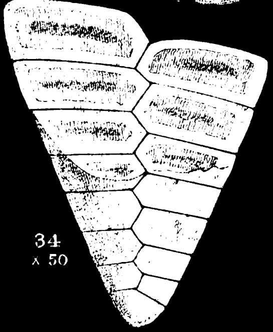

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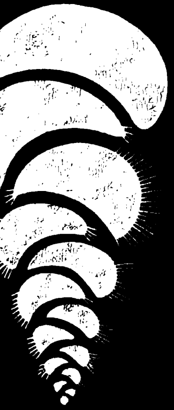

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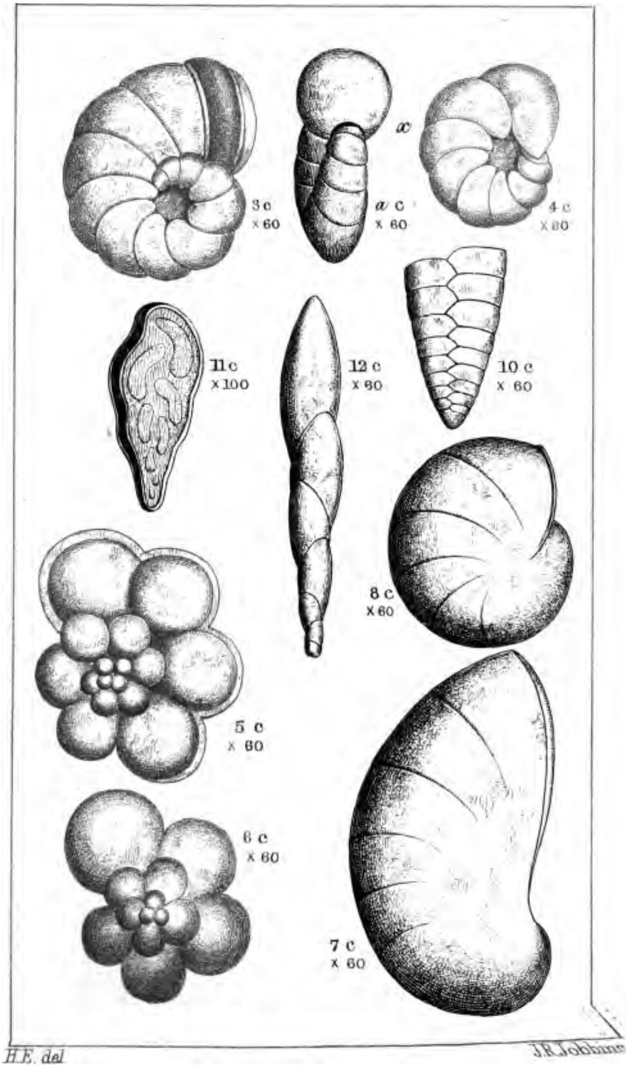
Pl. VII facing p. 31

Plate VIII.



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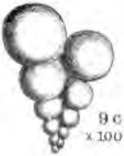
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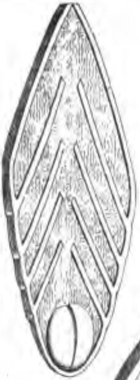
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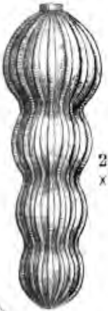
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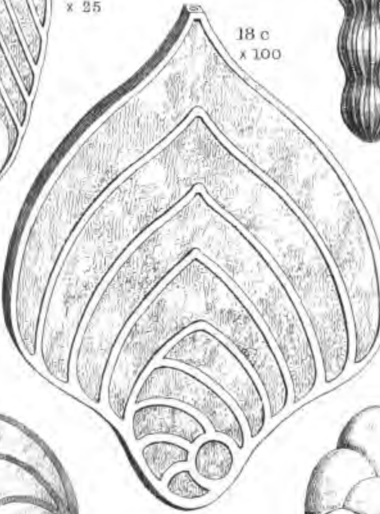
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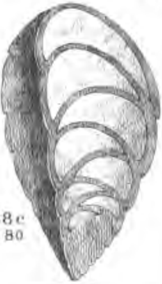
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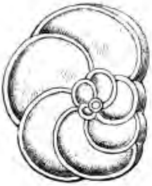
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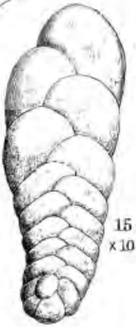
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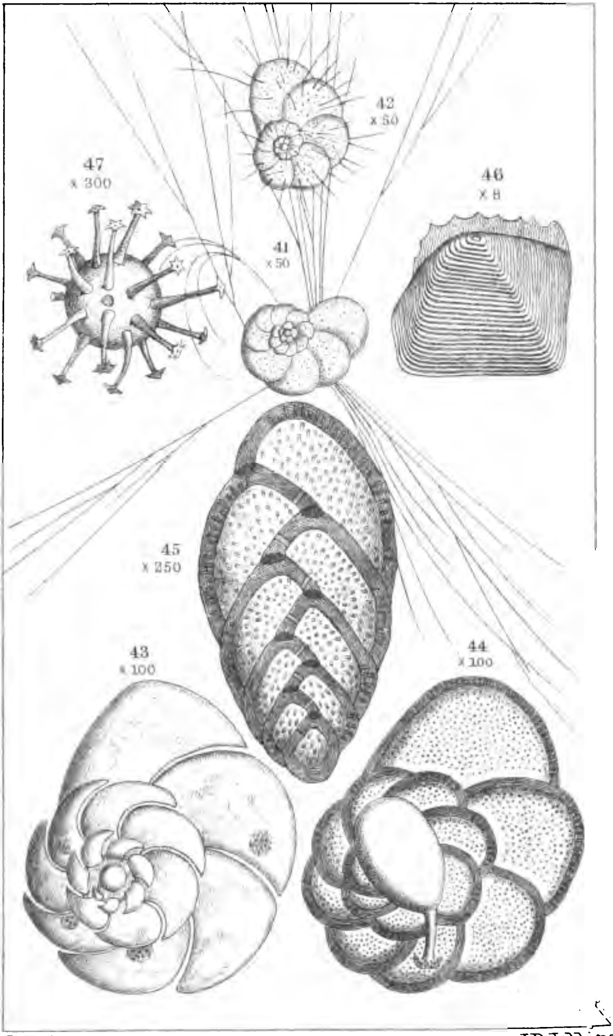

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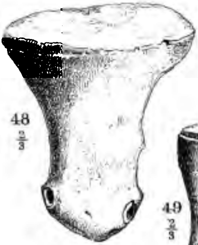
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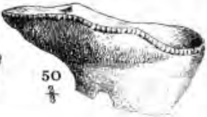
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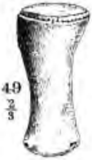
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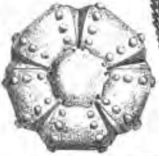
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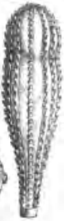
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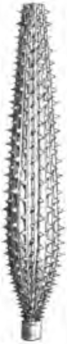
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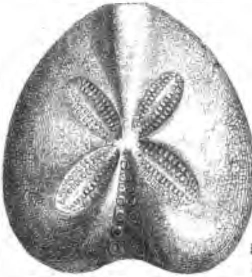
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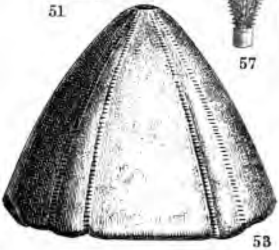
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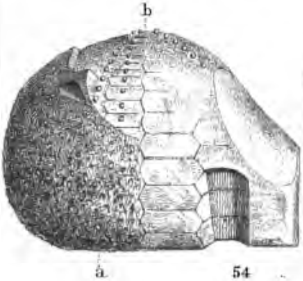

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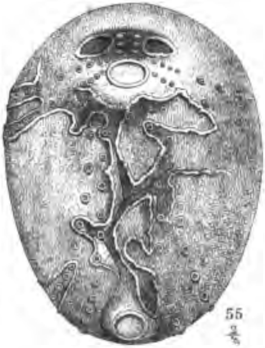
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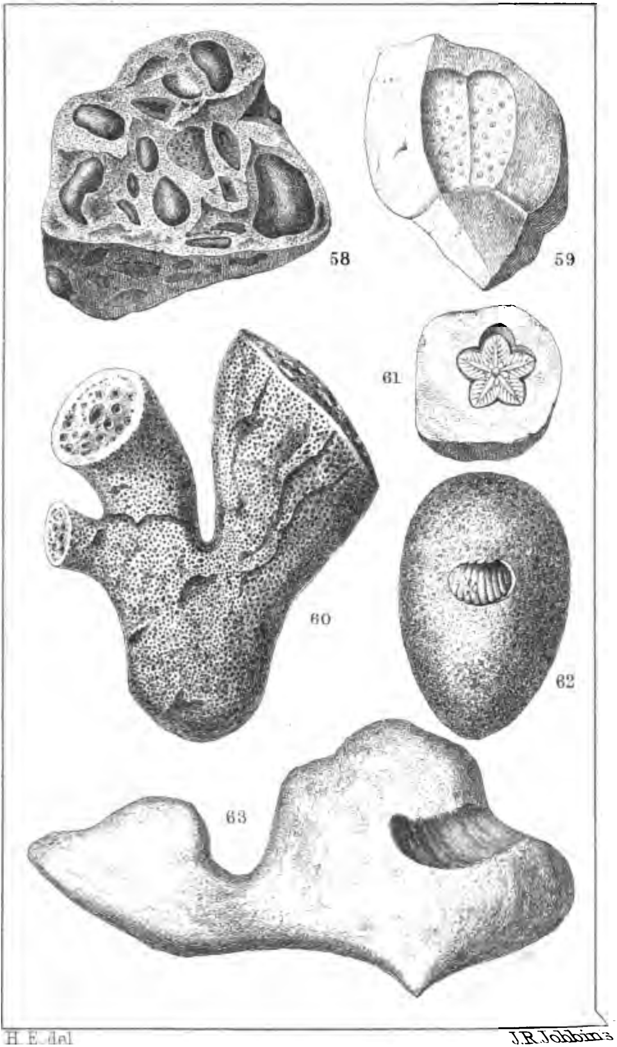
Plate XII



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